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Status of Sugar and Western White Pines on Federal Forest Lands in Southwest Oregon:

Inventory Query and Natural Stand Survey Results

Ellen Michaels Goheen and Donald J. Goheen
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EXECUTIVE SUMMARY

Sugar pines and western white pines are trees with great aesthetic, ecological, and economic value. Evidence is accumulating that they are being threatened by the combination of white pine blister rust, caused by the fungus *Cronartium ribicola*, infestation by mountain pine beetle (*Dendroctonus ponderosae*), and substantial increases in forest stocking associated with fire exclusion. To determine the distribution and condition of sugar pines and western white pines in Southwest Oregon, we queried data from permanent inventory plots from all ownerships, and we intensively surveyed randomly selected natural stands on federal lands.

Queried inventory plot data showed that across all ownerships and stand conditions in Southwest Oregon, five-needle pines were present in 31 percent of the 2,749 permanent plots examined. The percentage of plots containing five-needle pines in Southwest Oregon was twice as high as the average for the entire Pacific Northwest. White pine blister rust and bark beetles were the main mortality agents of five-needle pines identified in permanent inventory plots.

On USDA Forest Service and USDI Bureau of Land Management lands, intensive surveys were done of 55 stands with sugar pine components and 55 stands with western white pine components. On average for all trees in the sugar pine stands, sugar pines constituted 5 percent of the stocking and 17 percent of the basal area. Thirteen percent of the sugar pines were dead, containing 30 percent of the sugar pine basal area. White pine blister rust was detected on sugar pines in 53 of the 55 survey stands and was identified in 51 percent of the plots that contained sugar pines. On average, 20 percent of all sugar pine trees had detectable *C. ribicola* infections: 16 percent of all live sugar pines and 53 percent of all dead sugar pines.

On average for all trees in surveyed western white pine stands, western white pines made up 18 percent of the stocking and 15 percent of the basal area. Of the western white pine

[1] *Plant Pathologist, USDA Forest Service, Forest Health Protection, Southwest Oregon Forest Insect and Disease Service Center, Central Point, OR*

[2] *Plant Pathologist/Entomologist, Retired, USDA Forest Service, Forest Health Protection, Southwest Oregon Forest Insect and Disease Service Center, Jacksonville, OR*

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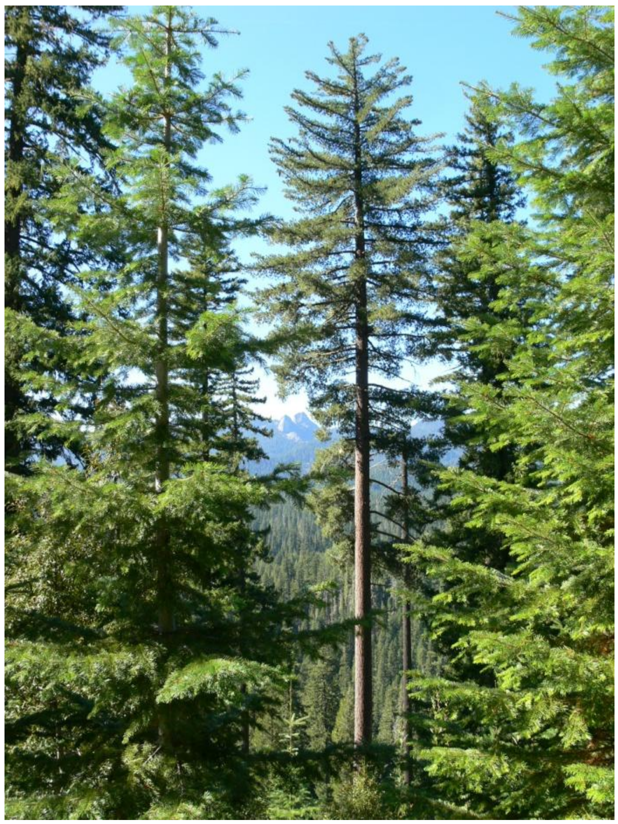
trees, 17 percent, containing half of the species' basal area, were dead. White pine blister rust was detected on western white pines in 51 of the 55 survey stands and was identified in 67 percent of the plots that contained western white pines. On average, 30 percent of all western white pine trees living and dead had detectable *C. ribicola* infections: 29 percent of all live and 55 percent of all dead western white pines. Impacts of white pine blister rust for both host species varied by Plant Association, slope, aspect, elevation, and topographic position.

Sugar pines killed by mountain pine beetles were encountered in 84 percent of sugar pine survey stands. Among all dead sugar pine trees 12.7 cm dbh or greater, 73 percent had been infested by mountain pine beetles. Mountain pine beetle-killed western white pines were encountered in 84 percent of western white pine survey stands. Among all dead western white pine trees of 12.7 cm or greater dbh, 69 percent had been infested by mountain pine beetles. Other agents, including root diseases, dwarf mistletoes, and pine engraver beetles, also influence five-needle pine health in Southwest Oregon but to a much lesser extent than white pine blister rust or mountain pine beetles.

Based on our surveys, we believe that the present level of mortality exhibited by sugar and western white pines in Southwest Oregon forests is high and a matter for concern. Mortality of five-needle pines was greater than mortality of all other tree species encountered in surveyed stands. Recommendations to manage for the continued presence of five-needle pines and to ensure their health in Southwest Oregon include: 1) incorporating sugar and western white pines in management prescriptions where appropriate, 2) ensuring successful sugar and western white pine regeneration by using site-adapted, white pine blister rust-resistant stock, 3) evaluating the need and timing of pruning and thinning in young stand management prescriptions, 4) spacing medium- to large-sized sugar and western white pines to prevent mountain pine beetle infestation, and 5) promoting fire survival of five-needle pine stand components.



INTRODUCTION

Southwest Oregon is a region of high climatic, geologic, and floristic diversity (Whittaker 1960, Atzet and Martin 1991). Twenty-six species of conifers are found in the forests of the region including three species of five-needle pines: sugar pine (*Pinus lambertiana*), western white pine (*P. monticola*), and whitebark pine (*P. albicaulis*). Sugar pines (figs. 1 and 2) are widely distributed in Southwest Oregon mixed conifer forests and are encountered on a variety of sites at elevations from 335 m to 1645 m (1000 to 5000 ft)). Western white pines (fig. 3) are also widely distributed in Southwest Oregon. They are found at higher elevations in the Cascades usually from 1300 to 1975 m (3900 to 6000 ft), on the flats along the upper reaches of the Rogue and Umpqua Rivers at elevations from 1000 to 1600 m (3000 to 4800 ft), and on ultramafic soils in the Siskiyou Mountains at a range of elevations from 600 to 1600 m (1800 to 4800 ft). Whitebark pines occur at the highest elevations on the Cascade crest (usually above 1975 m (6000 ft)) and in scattered island populations such as on Mt. Ashland in the Siskiyou Mountains. Sugar and western white pines have significant scenic, wildlife, and watershed values and are also valuable timber trees. They possess a number of desirable traits including great growth potential, ability to reach substantial ages and sizes, capacity to survive and grow on infertile soils, superior wind firmness, resistance to native root pathogens, and frost

Figure 1. Mature sugar pine, Southwest Oregon Cascades.

Figure 2. Sugar pine regeneration, Southwest Oregon Cascades.

hardiness. Whitebark pines are capable of tolerating the dramatic environmental extremes associated with their inhospitable mountaintop habitats and are important pioneer species, facilitating the establishment of other tree species and playing a significant role in watershed protection. They also have considerable wildlife and aesthetic values. All three of the five-needle pines contribute significantly to ecological diversity in the forests of Southwest Oregon.


Figure 3. Mixed conifer stand in Southwest OregonCascades with mature and regenerating western white pine.

Five-needle pines throughout the West face serious health threats and the Southwest Oregon populations are no exceptions. The most critical of these threats result from 1) widespread occurrence of the extremely virulent, non-native fungal pathogen, *Cronartium ribicola*, cause of white pine blister rust, and 2) vulnerability to high levels of infestation by bark beetles, especially mountain pine beetles (*Dendroctonus ponderosae*).

Cronartium ribicola is a five-needle pine pathogen with a complex life history. It requires an alternate host, usually a species in the genus *Ribes* (gooseberries and currants), to complete its life-cycle. Originally from Asia, *C. ribicola* spread south and west into Europe during the eighteenth and nineteen centuries. It reached North America as an unintended consequence of movement of five-needle pine nursery stock from Europe. In western North America, Mielke (1943) reported it was introduced in 1910 at Vancouver, British Columbia on a single shipment of infected eastern white pines from France. Hunt (2009) speculates that it may actually have been introduced several times between 1910 and 1920 at more than one location along the Pacific Coast. In either event, it was not recognized until 1921 by which time it was already well established in native five-needle pine populations and spreading rapidly. *Cronartium ribicola* was first reported in Southwest Oregon in 1936 (Anonymous 1936). Backdating infections in the stands where the fungus was first reported indicated that it probably reached Southwest Oregon in the 1920s. The earliest backdated infection at Panther Mountain in Curry County showed a date of origin of 1926 (Mielke 1938). In Southwest Oregon, attempts to control white pine blister rust were begun almost as soon as the disease was discovered. Eradicating *Ribes* spp. from forest stands was most commonly employed. Unfortunately, this strategy proved ineffective in spite of major effort and investment.

On susceptible five-needle pine hosts, infection by *C. ribicola* results in formation of resinous branch and bole cankers that have a high potential to eventually girdle host stems, especially those of less than 20 cm (8 in) diameter (figs. 4-8). Infection leads to branch and top mortality of large diameter host trees and commonly results in entire tree death of small hosts when main stems are affected (figs. 8-10).

Figure 4. Diamond-shaped canker caused by *C. ribicola* on young western white pine.

The magnitude of impacts caused by a non-native pathogen is often much greater than that associated with a native disease organism because local hosts have not evolved with the introduced pathogen and thus have not developed resistance to it. This has certainly proven to be the case with *C. ribicola*. Since its introduction, decline of native five-needle pines attributed to this invasive pathogen has been substantial and has been viewed with great concern by forest managers and tree disease specialists in many parts of the West (Conklin et al. 2009, Harvey et al. 2008, Samman et al. 2003, van Mantgem et al. 2004). Significant impacts of white pine blister rust on five-needle pines in Southwest Oregon have been observed for some time, but have not been well quantified on an area-wide basis for sugar pine and western white pine. The white pine blister rust situation for whitebark pine in Southwest Oregon was recently evaluated (Goheen et al. 2002, Ward et al. 2006). Results from the survey along the Pacific Crest Trail in the environs of the Thielsen Wilderness indicated high levels of *C. ribicola* infection with 52 percent of all whitebark pine trees exhibiting detectable evidence of cankers.

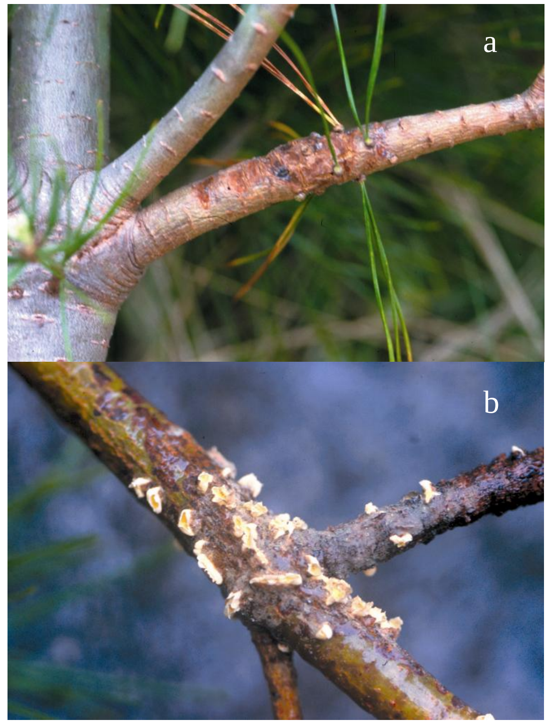


Figure 5. Initial indication of a white pine blister rust canker at the base of an infected needle.

Figure 6a. Spindle-shaped swelling on branch caused by *C. ribicola*. 6b. Yellow-orange aeciospores erupting from *C. ribicola*-caused blisters.

Figure 7. *C. ribicola* aeciospores erupting from blisters on a main stem canker.

Figure 8. Resin flow at base of young five-needle pine associated with a white pine blister rust canker.

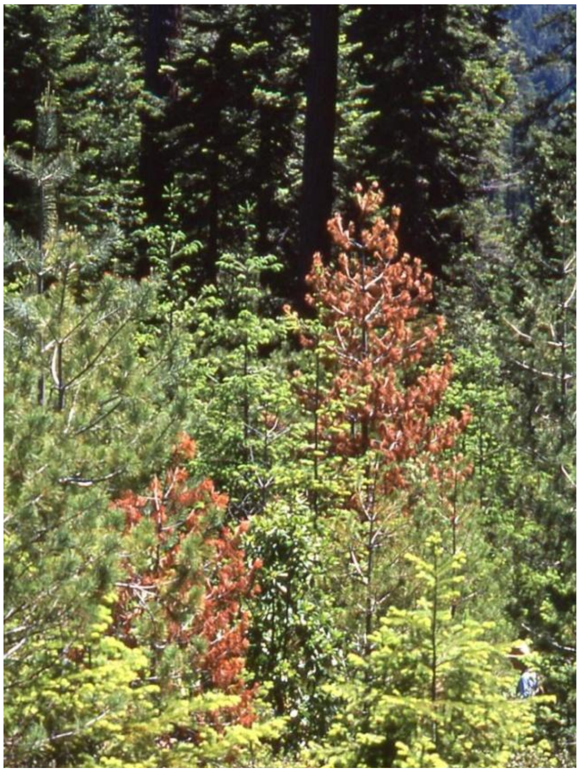


Figure 9. Western white pine regeneration killed by white pine blister rust.

Figure 10. Topkill and branch dieback caused by *C. ribicola.*on a sugar pine.

Mountain pine beetles are native forest insects that breed in and kill a variety of pine species throughout the West (Gibson et al. 2009). They most commonly infest medium- to large-size host trees, those with diameters at breast height (dbh) of 20 cm (8 in) or greater, and are rarely found on trees under 12.7 cm (5 in) dbh (figs. 11-13). All three of the Southwest Oregon five-needle pines are hosts (Furniss and Carolin 1977).

Figure 11. Mountain pine beetle galleries under the bark of a recently-killed sugar pine.

When beetle populations are at endemic levels, mountain pine beetles usually do not infest healthy, vigorous pines (Gibson et al. 2009, Struble 1965). Rather, they prefer or are most successful on host trees that are under some degree of stress. White pine blister rust infections that kill tops and numerous branches on severely diseased five-needle pines may weaken the trees sufficiently to favor successful mountain pine beetle attack. Impacts of other diseases, lightning strikes, severe fire damage, and physical injuries also increase likelihood of bark beetle infestation. Another factor implicated as important in predisposing pines to mountain pine beetle infestation is overstocking. Pines growing in dense stands may not compete well for water and other resources and may be of low enough vigor to make them vulnerable to beetle attack. Cooler, shaded conditions in dense stands where trees are close together may also provide especially favorable environmental conditions for the beetles themselves during flight and the host selection process (Gibson et al. 2009). When mountain pine beetle populations increase to epidemic proportions, large numbers of hosts over substantial areas may be killed irrespective of tree or stand condition.

Figure 12. Mature sugar pine killed by mountain pine beetles.

Figure 13. Recent mortality of western white pines caused by mountain pine beetles.

No large-scale, area-wide, ground-based surveys of the impacts of mountain pine beetle infestation on western white and sugar pines have been undertaken in Southwest Oregon. However, mortality estimates from Regional aerial sketchmap surveys done annually in the area since 1951 do exist. These aerial sketchmap surveys were designed to provide data on trends in tree mortality and give estimates on the general magnitude of insect activity. They were not intended to give precise results regarding numbers of trees killed. Aerial observers tended to key in on groups and patches of dead trees and often underestimated effects of scattered mortality. Nevertheless, aerial survey results are quite interesting. Mortality of western white pines attributed to mountain pine beetle infestation was first mapped in aerial surveys in Southwest Oregon in 1953. Substantial mountain pine beetle activity involving the killing of tens of thousands of large, old western white pines was mapped during the 1960s (Dolph, undated, Dolph and Pettinger 1968). Numerous dead and dying trees were salvaged, but many large standing dead and downed western white pines associated with the 1960s outbreak can still be found in Cascade Mountain stands. Since the 1960s, aerial surveys have detected only limited mortality of western white pines. Mortality in sugar pine attributed to mountain pine beetles was also first mapped in Southwest Oregon in 1953. Subsequently, the 1964 and 1965 conditions reports described low to moderate tree killing in mature sugar pine stand components associated with damage from the 1962 Columbus Day storm (Dolph, undated, Orr et al. 1965, Orr et al. 1966). Increased amounts of mortality were observed in the mid to late 1970s and even more mortality was mapped in the late 1980s and early 1990s (Pacific Northwest Region Aerial Survey data). During this time, areas in which infested sugar pines were observed were large but numbers of dead trees detected were relatively small, reflecting sugar pine's occurrence as a minor species with a widely scattered distribution on the landscape. A few site-specific ground-based surveys in Southwest Oregon stands suggest that levels of mountain pine beetle activity are now substantial and possibly increasing in sugar and western white pines (Goheen et al. 1997, Atzet, personal communication).

An evaluation of whitebark pines in the Southwest Oregon Cascades (Goheen et al. 2002) indicated that mountain pine beetles were significant in contributing to mortality in mature trees of that species (fig. 14). Evidence of infestation was found on 31 percent of all dead whitebark pines examined and was almost universally present on larger dead trees (those exceeding 20 cm (8 in) dbh).

Figure 14. Whitebark pine mortality caused by mountain pine beetles and white pine blister rust, Mt Thielsen Wilderness, Oregon Cascades.

OBJECTIVES

The objectives of our evaluation were to:

- gather information from recent inventories on Southwest Oregon five-needle pine distribution and condition,
- conduct additional intensive surveys to evaluate the health of sugar pines and western white pines in natural stands in the area,
- examine the influence of some stand and site factors on diseases and insects that are currently affecting sugar and western white pines, and
- establish a benchmark of information on the health of these species for comparison in the future.

Though our emphasis was on the impacts of white pine blister rust and mountain pine beetles, we also examined other agents that affect five-needle pines in Southwest Oregon. In this evaluation, we concentrated on the condition of sugar and western white pines since whitebark pine health has been recently investigated (Goheen et al 2002, Ward et al 2006).

METHODS

Inventory Data- Queries were made of the 1991 to 2000 data from the 15,232 Forest Inventory and Analysis (FIA) and Continuous Vegetation Survey (CVS) plots distributed across Oregon and Washington and those portions of California administered by the Rogue River-Siskiyou National Forest. All forested lands in the Pacific Northwest are covered in the inventory plot layout, with survey points arranged on a systematic 2.7 km (1.7 mi) grid on most Forest Service land and on a 5.5 km (3.4 mi) grid in Forest Service wilderness areas and on Bureau of Land Management and State and private lands. Occurrence and distribution of sugar, western white, and whitebark pines were determined for the entire area. Data on reported occurrence of white pine blister rust and mountain pine beetle infestation were obtained for trees that had insect and disease information collected (those over 2.5 cm (1.0) dbh). Although it also is a five-needle pine species native to limited areas in the Pacific Northwest, limber pine (*P. flexilis*) was not included in our data query because it does not occur in Southwest Oregon, the focus area for this evaluation.

Inventory data specific for Southwest Oregon were obtained by examining results for the 2,749 FIA and CVS plots established from1993 to 1997 in Coos, Curry, Douglas, Jackson, Josephine, and Lane Counties, Oregon and that portion of the Rogue River-Siskiyou National Forest in Del Norte and Siskiyou Counties, California. The same kind of incidence, distribution, and insect and disease data were obtained for the five-needle pines in the Southwest Oregon area as for the entire Pacific Northwest.

Intensive Surveys of the Condition of Sugar Pine and Western White Pine Components in Natural Stands- In 2002 and 2003, intensive ground surveys were done in 110 natural stands on federal lands in Southwest Oregon: 55 stands selected for their probable sugar pine components and 55 for their probable western white pine components. For the purpose of this evaluation, a natural stand was defined as a relatively uniform forest stand that occurred on a contiguous area of eight hectares (20 acres) or greater, that had regenerated naturally, and that contained a substantial number of trees over 50-years-old. Since our intent was to examine sugar pine and western white pine health and demographics, we wanted to concentrate our survey efforts in stands that had a high probability of containing at least some components of one or the other of those species. Therefore, for eight years prior to the surveys we compiled master lists of stands with a high probability of the occurrence of sugar pines or western white pines from federal lands throughout Southwest Oregon and the portion of the Rogue River-Siskiyou National Forest in California. Lists were based on Southwest Oregon ecology plot data that showed presence of sugar or western white pines, records of five-needle pine genetic selection locations, and information on pine stands derived from discussions with forest managers. Random selections for survey were made from these lists. There was no prior knowledge of tree condition or stocking in selected stands except that 55 were chosen from stands likely to have a sugar pine component and 55 from stands likely to have a western white pine component.

In each selected stand, a ten-point stand examination was done. Five points were located at 60 m (180 ft) intervals along each of two transect lines situated parallel to each other and 100 m (300 ft) apart. Geographic Positioning Systems (GPS) coordinates were recorded for the start of the first transect. At each point on both transects, a nested variable-radius plot and fixed-area plot were established. A 20- or 40-Basal Area Factor (BAF) was used to define the variable-radius plot. BAF was chosen based on stand stocking levels; the same BAF was used for all ten points within a stand. The fixed-area plot was either a 0.004 hectare (0.01 acre) circular plot in stands with western white pine components or a 0.02 hectare (0.05 acre) circular plot in stands with sugar pine components.

Starting from the northern-most tree within each variable-radius plot , all “in” trees with a diameter at breast height (1.37 m (4.5 ft)) (dbh) of 12.7 cm (5.0 in) or greater were consecutively numbered, measured, and examined. The following data were collected for each tree:

- Species
- Dbh
- Condition (live healthy, live symptomatic, dead for five years or less, dead for more than five years, or, stump of harvested tree if $\geq$ 10 inches diameter and having intact bark on at least 25 percent of its circumference.)
- Presence of insect infestation, pathogen occurrence, or other damage or injury
- Severity of each damaging agent or injury
- White pine blister rust severity rating (for individual five-needle pine trees):
    - **1** Distance from nearest margins of all branch cankers to stem >61 cm (24 in),
    - **2** Distance from nearest margin of any branch canker to stem between 15 and 61 cm (6-24 in).
    - **3** Distance from nearest margin of any branch canker to stem <15 cm (6 in) or canker actually on bole.

- Evidence of wildlife use as defined by the presence of any excavations or cavities > 2.5 cm (1.0 in)diameter

Within fixed-area plots, all trees with dbh of less than 12.7 cm (5.0 in) were tallied by each appropriate combination of species, condition, dbh class, and damaging agent or injury present. Fixed-area plot trees were then grouped as either seedlings (trees greater than 15 cm (6 in) tall and less than 1.4 m (4.5 ft) tall (no dbh)) and saplings (trees with dbhs of 0.1 to 12.6 cm (0.1 to 4.9 in)).

For each plot in all survey stands, the following additional information was collected:

- Occurrence and percent cover of *Ribes* spp. on 0.02 hectare (0.05 acre) circular area surrounding plot center. *Ribes* plants were not evaluated for infection by *C. ribicola* nor did we distinguish among different *Ribes* species when calculating percent cover.
- Root disease severity rating (RDSR) using the system devised by Hagle (1985) (table 1) on 0.02 hectare (0.05 acre) circular area surrounding plot center.

Table 1—Root disease severity rating (RDSR) for plots

Rating	Rating definition
0	No evidence of root disease
1	Root disease not on plot, but present within 15 m of plot edge
2	Minor evidence of root disease (i.e., one suppressed tree killed)
3	Canopy reduction up to 20 percent
4	Canopy reduction 20 to 30 percent
5	Canopy reduction 30-50 percent
6	Canopy reduction 50-75 percent
7	Over 75 percent canopy reduction
8	Only 1 overstory tree remaining due to root disease
9	No overstory trees remaining

For each of the stands surveyed, the following additional information was collected:

- Average percent slope
- Aspect
- Average elevation
- Slope position
- Predominant Plant Association (Atzet et al. 1996)
- Evidence of disturbance (past logging, fire, wind)

Number of trees per hectare (trees per acre) was calculated for trees of all sizes and m^2 basal area per hectare (ft^2 basal area per acre) was calculated for trees 12.7 cm (5.0 in) dbh and greater from the variable-radius plot data for each sample stand and all stands combined for sugar pine and western white pine respectively. Results were grouped by species, condition, diameter class, and damaging agent. Trees greater than 12.7 cm (5.0 in) were grouped by size into 3 categories: Small 12.7-25.3 cm (5.0-9.9 in) dbh; Medium 25.4-50.8 cm (10.0-20.0 in) dbh; Large > 50.9 cm (20.0 in) dbh. The number of trees per hectare (trees per acre) less than 12.7 cm (5.0 in) dbh was calculated from the fixed plot data for each sample stand and all stands combined for sugar pine and western white pine respectively by species, condition, diameter class, and damaging agent. Means and standard errors were calculated on metric data using the data analysis package in Microsoft Excel 2000.

Data for all 110 five-needle pine stands surveyed were pooled to examine the influence of site conditions and occurrence of alternate hosts on white pine blister rust severity. Stands were classified as having either light to moderate or severe levels of white pine blister rust infection in their five-needle pine components. For the purpose of this evaluation, stands with more than 35 percent of the live host trees of all sizes taller than 1.4 m (4.5 ft) infected by *C. ribicola* were considered severely diseased while those with less than or equal to 35 percent infection levels were considered lightly to moderately diseased. Stands in which no white pine blister rust was detected were included with the lightly to moderately diseased stands. Thirty-five percent is a locally used threshold based on management recommendations. In Southwest Oregon, we recommend against using natural regeneration or unimproved five-needle pine planting stock in silvicultural prescriptions if more than 35 percent of the host trees in the previously existing stand on that site exhibited *C. ribicola* infections. Alternatively, we recommend that only genetically-improved white pine blister rust-resistant planting stock be used on such sites. For each factor considered in the current surveys, the proportion of sample stands in the severe category was compared with the proportion of stands in the lightly to moderately diseased category.

The mean basal area (m^2 per hectare (ft^2 per acre)) of all tree species for sample plots in each survey stand that contained bark beetle-infested five-needle pines and the mean basal area for plots that had healthy five-needle pine hosts of 12.7 cm (5.0 in) or greater dbh were compared to investigate the role that stand density played in influencing likelihood of bark beetle infestation. Mean dbh for infested and uninfested hosts were also compared. In addition, for mountain pine beetles, occurrence and severity of infestation in five-needle pines were compared to those for other potential pine host species (ponderosa and lodgepole pines) occurring in the same sample stands as the five-needle pines.

Percent occurrence of detected wildlife excavation use was compared by tree species, condition, and size class for the sampled stands.

RESULTS

Inventory data- For all inventoried lands in Oregon and Washington, sugar pines, western white pines, and whitebark pines were reported in 2,128 of the 15,232 FIA and CVS inventory plots (14 percent) (fig. 15). Western white pines occurred in 58 percent of these plots, sugar pines in 32 percent, and whitebark pines in 16 percent. Pine mortality was detected in 24 percent of the plots that contained five-needle pines, and hosts infested by mountain pine beetles were identified in 11 percent of the plots exhibiting mortality. White pine blister rust was identified in 559 plots (26 percent of all plots containing sugar, western white, and/or whitebark pines).

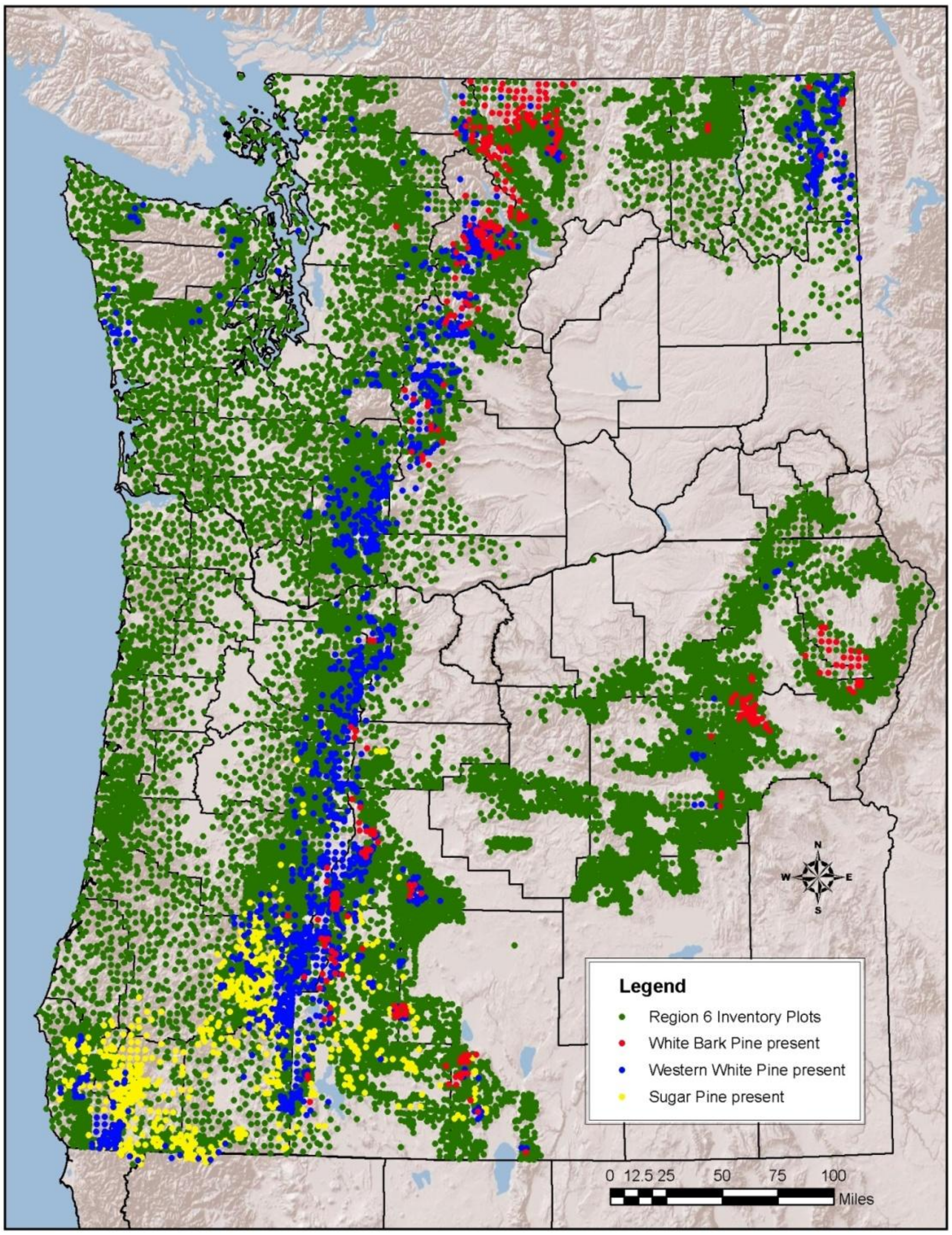


Figure 15. Location of inventory plots queried in Oregon, Washington, and California.

For Southwest Oregon, five-needle pines were reported in 860 (31 percent) of the 2,749 inventory plots examined (fig. 16). Sugar pines occurred in 64 percent of the five-needle pine plots, western white pines in 53 percent, and whitebark pines in 0.5 percent. On plots with five-needle pines, five-needle pine stocking averaged six percent of total trees per acre. White pine blister rust was identified in 234 inventory plots (27 percent of all plots containing five-needle pines) and was associated with an average of 74 percent of all dead five-needle pines on inventory plots. An average of 32 percent of live five-needle pine stocking was identified as infected. Bark beetle-caused mortality was recorded on 91 (10 percent) of the five-needle pine plots. Bark beetles were associated with 86 percent of all dead five-needle pines.

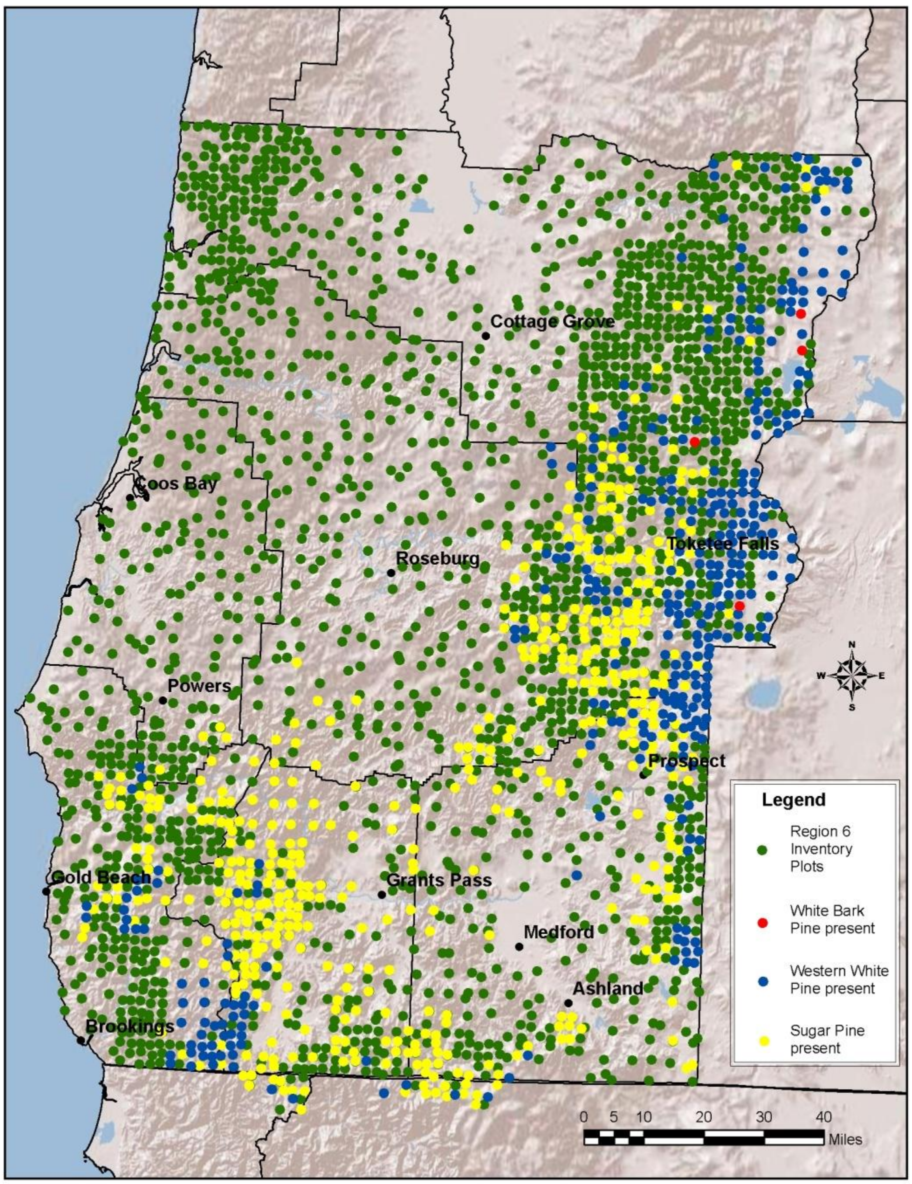


Figure 16. Location of inventory plots queried in Southwest Oregon and Northern California.

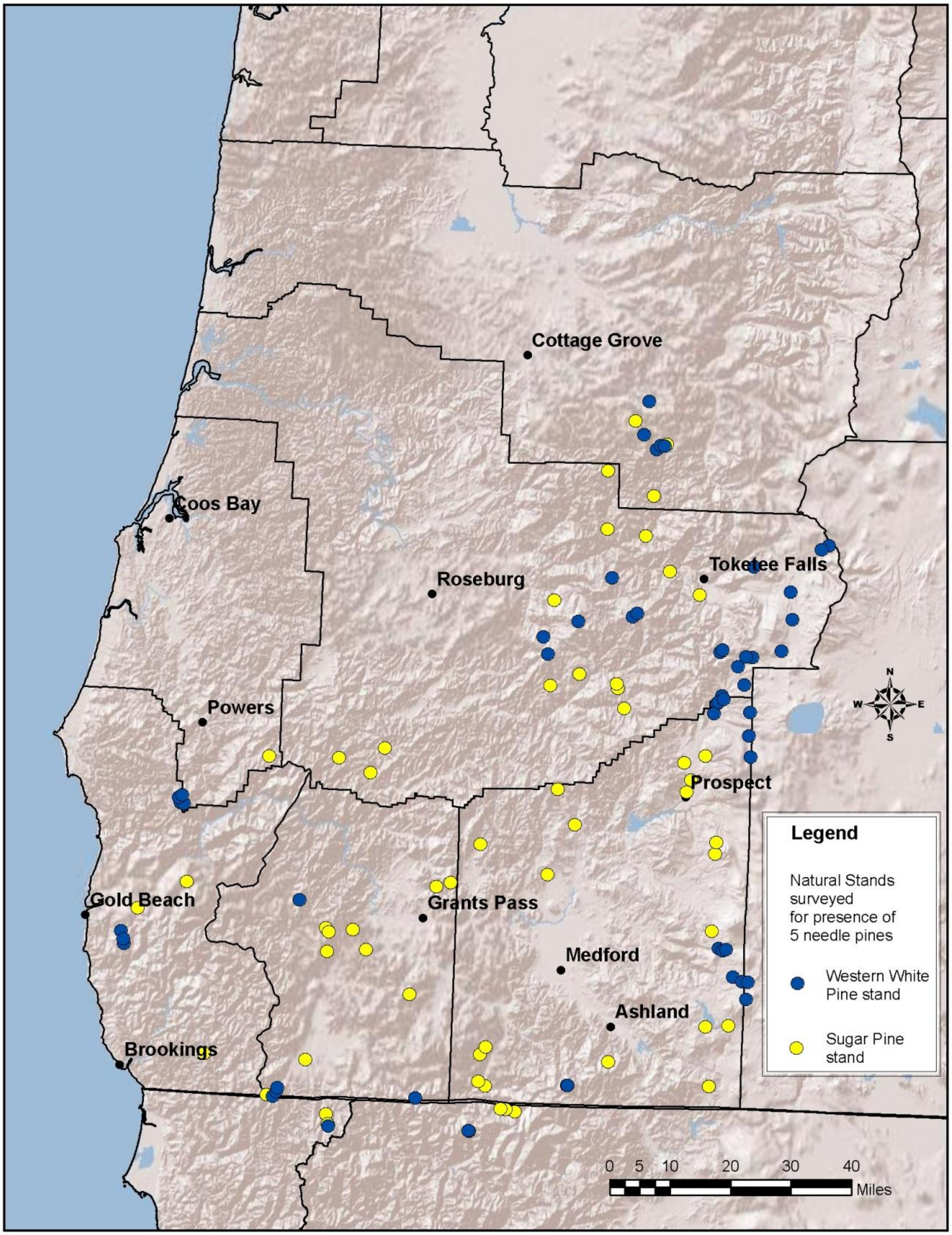


Figure 17. Location of the 55 sugar pine (yellow) and 55 western white pine (blue) stands in Southwest Oregon and adjacent northern California that were intensively surveyed.

Condition of Sugar Pines in Natural Stands on Federal Lands in Southwest Oregon

Locations of the 55 natural stands that were intensively surveyed for sugar pine condition in this evaluation are shown in Figure 17. The selected stands were well distributed across the federal lands in Southwest Oregon that are within the native range of sugar pine. All surveyed stands did indeed have sugar pine components, and, in fact, 454 of the total 550 plots in all stands (82 percent) contained at least one sugar pine.

Among other tree species in surveyed stands, Douglas-fir (*Pseudotsuga menziesii*) was by far the most common and widely distributed. White fir (*Abies concolor*), incense-cedar (*Calocedrus decurrens*), ponderosa pine (*Pinus ponderosa*), Pacific madrone (*Arbutus menziesii*), and western hemlock (*Tsuga heterophylla*) were also common and widely distributed stand components. Less plentiful and/or widely distributed tree species were in declining order California black oak (*Quercus kelloggii*), golden chinquapin (*Castanopsis chrysophylla*), canyon live oak (*Quercus chrysolepis*), tanoak (*Notholithocarpus densiflora*), Pacific yew (*Taxus brevifolia*), Jeffrey pine (*Pinus jeffreyi*), Port-Orford-cedar (*Chamaecyparis lawsoniana*), knobcone pine (*Pinus attenuata*), western redcedar (*Thuja plicata*), and big leaf maple (*Acer macrophyllum*). Western white pines were encountered in small numbers in two (four percent) of the stands that had been chosen specifically for sugar pine survey.

Sugar pine survey stands fell into 32 different Plant Associations in four Plant Series (Atzet et al. 1996). Appendix table 1 shows the frequency of occurrence in different Plant Associations. Forty-two percent of survey stands were in the Douglas-fir Series, 33 percent in the White Fir Series, 14 percent in the Tanoak Series, and 11percent were classified in the Western Hemlock Series. Six (11 percent) of the sugar pine stands surveyed occurred on ultramaphic (serpentine or peridotite) soil types.

Sixteen of the survey stands (29 percent) had no visible evidence of harvest entries prior to this survey. The remaining 39 (71 percent) had experienced some level of individual tree selection or small group selection harvest. Thirty-four of the stands (62 percent) showed clear evidence of past wind-throw events, and 28 (51 percent) had experienced past fires of sufficient magnitude to cause readily detectable fire scars on a substantial number of large trees.

On average for all trees (living and dead) in the survey stands, sugar pines (fig. 18) constituted 5 percent of the stocking (table 2, fig. 19) and 17 percent of the basal area (table 3, fig. 20). Thirteen percent of the sugar pines and 30 percent of the sugar pine basal area was accounted for by dead trees. There was also an average of 4.7 sugar pine stumps containing 1.3 m² of basal area per hectare (5.7 ft^2 per acre).


Figure 18. Large sugar pine encountered in intensive stand survey.

Table 2. Mean numbers of trees per hectare (stems per acre) in 55 randomly selected natural stands with sugar pine components surveyed in Southwest Oregon.

Species/ Size Category	**Stems per Hectare** (stems per acre)	**Standard Error** *Based on stems per hectare*	**Range** In stems per hectare (stems per acre)
Sugar Pine			
Live Seedlings[1]	81.5 (33.0)	14.5	0-627.6 (0- 253.9)
Live Saplings[2]	45.3 (18.3)	12.9	0-682.0 (0-276.0)
Live Small[3]	13.6 (5.5)	3.1	0-89.7 (0-36.3)
Live Medium[4]	7.0 (2.8)	1.2	0-44.8 (0-18.1)
Live Large[5]	7.0 (2.8)	0.7	0-23.7 (0-9.6)
All Live	154.5 (62.5)	24.5	2.8-1152.0 (1.1-466.2)
Dead Seedlings[1]	2.9 (1.2)	0.8	0-39.5 (0-16.0)
Dead Saplings[2]	9.5 (3.8)	1.8	0-69.5 (0-28.1)
Dead Small[3]	2.8 (1.1)	1.2	0-53.5 (0-21.7)
Dead Medium[4]	4.8 (1.9)	1.2	0-36.7 (0-14.9)
Dead Large[5]	2.7 (1.1)	0.5	0-25.9 (0-10.5
All Dead	22.7 (9.2)	3.3	0-143.5 (0-58.1)
Stumps	4.7 (1.9)	1.5	0-51.0 (0-20.6)
All Other Tree Species			
Live Seedlings[1]	1486.1 (601.4)	186.0	0-6399.6 (0-2590.0)
Live Saplings[2]	1077.3 (436.0)	99.2	49.4-3236.9 (20.1-1310.0)
Live Small[3]/Medium[4]/Large[5]	360.7 (146.0)	25.9	69.1-1105.1 (28.0-447.2)
All Live	2924.1 (1183.4)	233.5	366.5-9777.4 (148.3-3957.0))
Dead Seedlings	22.5 (9.1)	5.1	0-173.0 (0-70.0)
Dead Saplings	96.6 (39.1)	15.2	0-494.2 (0-200.0)
Dead Small[3]/Medium[4]/Large[5]	42.6 (17.2)	5.4	0-184.6 (0-74.7)
All Dead	161.7 (65.4)	19.6	0-629.4 (0-254.7)
Stumps	19.7 (8.0)	3.9	0-133.7 (0-54.1)

[1]Seedlings = trees less than 1.4 m tall (4.5 ft) (no dbh); [2]Saplings = trees with dbh of 0.1 to 12.6 cm (0.1 to 4.9 in);
[3]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [4]Medium 25.4-50.8 cm (10-20.0 in) dbh; [5]Large ≥ 50.9 cm (20 in) dbh

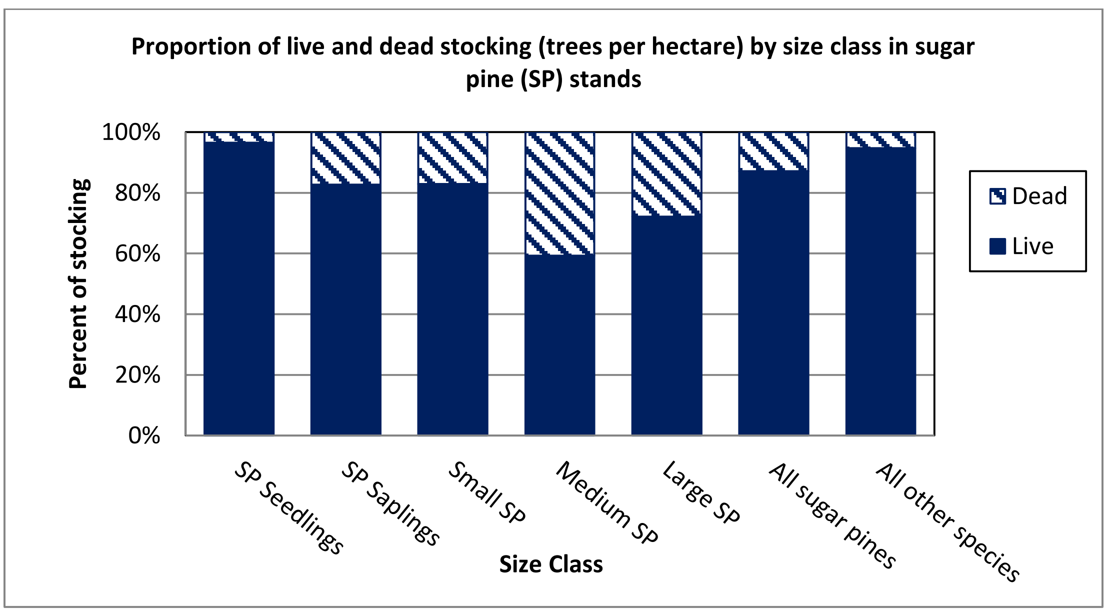


Figure 19. Proportion of live and dead stocking (trees per hectare) by size class in sugar pine stands.

Table 3. Mean basal area in 55 randomly selected natural stands with sugar pine components surveyed in Southwest Oregon			
Species/Size Category	**Basal Area in m² per hectare** (ft² per acre)	**Standard Error** *(Based on m² per hectare)*	**Range in m² per acre** (ft² per acre)
Sugar Pine			
Live Small[1]	0.36 (1.57)	0.08	0-2.29 (0-9.98)
Live Medium[2]	0.85 (3.70)	0.14	0-5.97 (0-26.00)
Live Large[3]	4.12 (17.95)	0.49	0-22.95 (0-99.97)
All Live	5.34 (23.26)	0.49	0-22.96 (0-100.01)
Dead Small[1]	0.08 (0.35)	0.03	0-1.38 (6.01)
Dead Medium[2]	0.59 (2.57)	0.13	0-4.13 (0-17.99)
Dead Large[3]	1.63 (7.10)	0.30	0-11.47 (0-49.96)
All Dead	2.22 (10.06)	0.35	0-12.86 (0-56.02)
Stumps	1.34 (5.84)	0.25	0-7.80 (0-33.98)
Other Tree Species			
Live (Small/Medium/Large)	31.66 (137.91)	1.81	6.89-57.85 (30.01-252.0)
Dead (Small/Medium/Large)	4.67 (20.34)	0.49	0-18.37 (0-80.02)
Stumps	4.14 (18.03)	0.61	0-17.91 (0-78.02)

[1]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [2]Medium 25.4-50.8 cm (10-20.0 in) dbh; [3]Large $\geq$ 50.9 cm (20 in) dbh

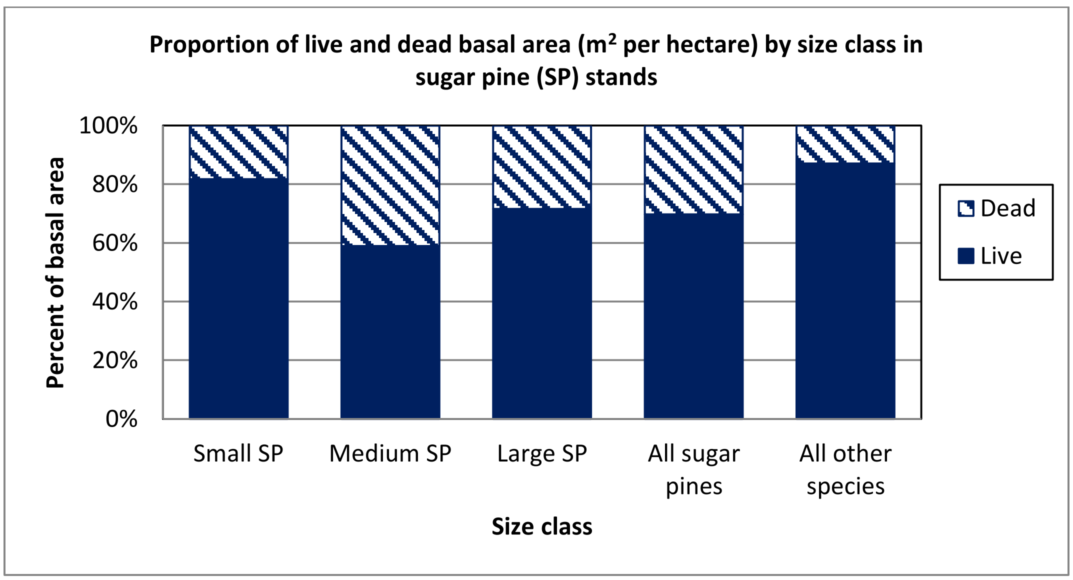


Figure 20. Proportion of live and dead basal area (m^2 per hectare) by size class in sugar pine stands.

White Pine Blister Rust

White pine blister rust was detected on sugar pines in 53 of the 55 survey stands (96 percent) and was identified in 232 of the 454 plots that contained sugar pines (51 percent). Amount of blister rust detected varied considerably among stands and plots. On average for all surveyed stands, 20 percent of all sugar pine trees had detectable *C. ribicola* infections (table 4): 16 percent of all live sugar pines and 53 percent of all dead sugar pines.

Table 4. Mean number of white pine blister rust-affected sugar pines (SP) in 55 randomly selected Southwest Oregon natural stands with sugar pine components.*

Category	**Mean number of infected SP per hectare** (infected SP per acre)	**Standard Error** *based on infected SP per hectare*	**Percent infected SP in category**
Live			
Live Seedlings[1]	5.5 (2.23)	1.0	9.8 (SE=2.4)
Live Saplings[2]	9.1 (22.5)	2.5	23.1 (SE=4.1)
Live Small[3]	1.8 (0.7)	0.7	17.3 (SE7.0)
Live Medium[4]	1.8 (0.7)	0.5	23.4 (SE=5.6)
Live Large[5]	2.3 (0.9)	0.4	33.3 (SE=4.4)
All Live	20.4 (8.25)	3.5	16.4 (SE=1.9)
Dead			
Dead Seedlings[1]	2.8 (1.1)	0.8	94.4 (SE=5.6)
Dead Saplings[2]	8.3 (3.4)	1.8	81.7 (SE=6.7)
Dead Small[3]	1.2 (0.5)	0.6	39.5 (SE=17.1)
Dead Medium[4]	0.6 (0.2)	0.4	8.6 (SE=4.8)
Dead Large[5]	0.3 (0.1)	0.1	10.5 (SE=3.4)
All Dead	13.3 (1.1)	2.6	53.5 (SE=5.3)
All	**33.7 (13.6)**	**5.5**	**20.1 (SE=1.9)**

[1]Seedlings = trees less than 1.4 m tall (4.5 ft) (no dbh); [2]Saplings = trees with dbh of 0.1 to 12.6 cm (0.1 to 4.9 in); [3]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [4]Medium 25.4-50.8 cm (10-20.0 in) dbh; [5]Large ≥ 50.9 cm (20 in) dbh

Host tree death associated with white pine blister rust was very high in smaller size classes of sugar pine (figs. 21 and 22). Ninety-four and 82 percent of the mortality in seedling and sapling sugar pines, respectively, was associated with white pine blister rust infections. Forty percent of dead sugar pines in the small tree category (12.7-25.3 cm (5.0-9.9 in) dbh) exhibited apparently lethal white pine blister rust cankers as well. In the medium and large sized sugar pine categories, detectable infections, though occurring on 9 and 11 percent of the dead trees respectively, were mainly on branches and tops and did not appear to contribute directly to whole-tree death.

Figure 21. Lethal canker on base of sapling sugar pine.

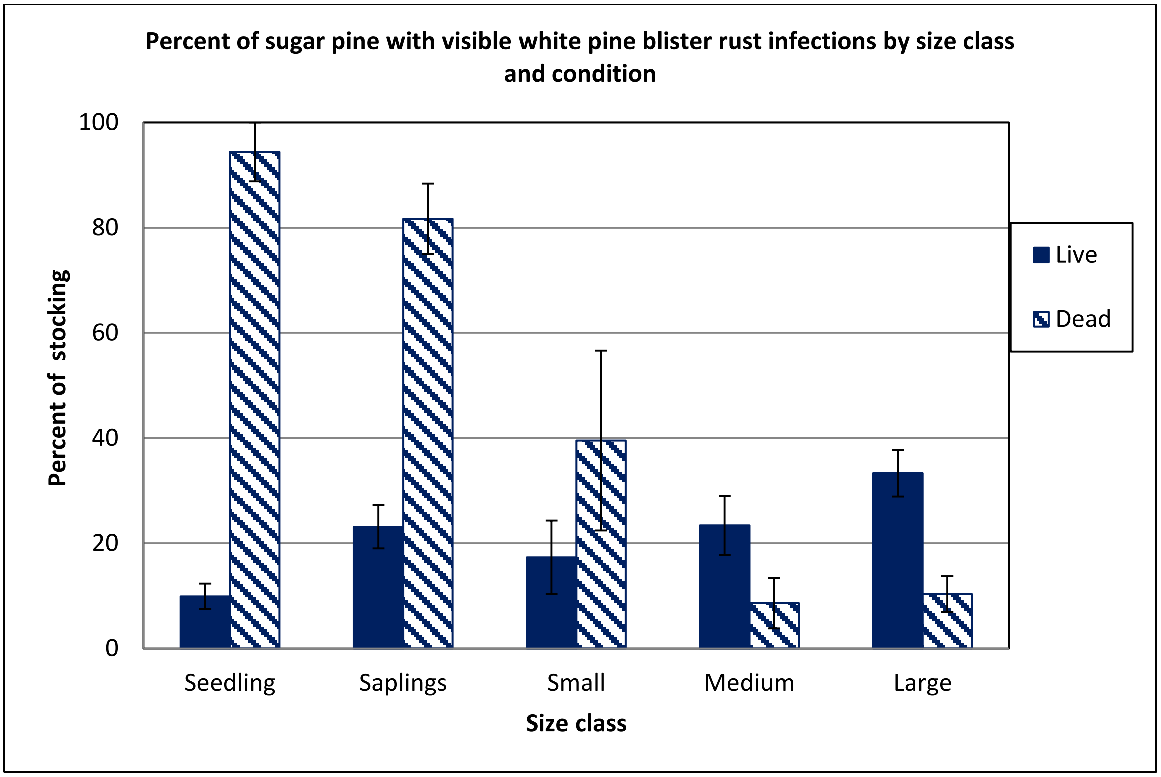


Figure 22. Percent of sugar pine with visible white pine blister rust infections by size class and condition. Bars indicate standard errors.

Figure 23. Severity 3 canker: canker within 15 cm (6 inches) of the bole.

Most of the live infected sugar pines exhibited blister rust cankers on their main stems or on branches within 15 cm (6 in) of the boles (WPBR Severity Rating 3) (figs. 23 and 24).

Severity Rating 3 infections on sapling and small-sized pines have a high potential to cause tree mortality in the not too distant future.

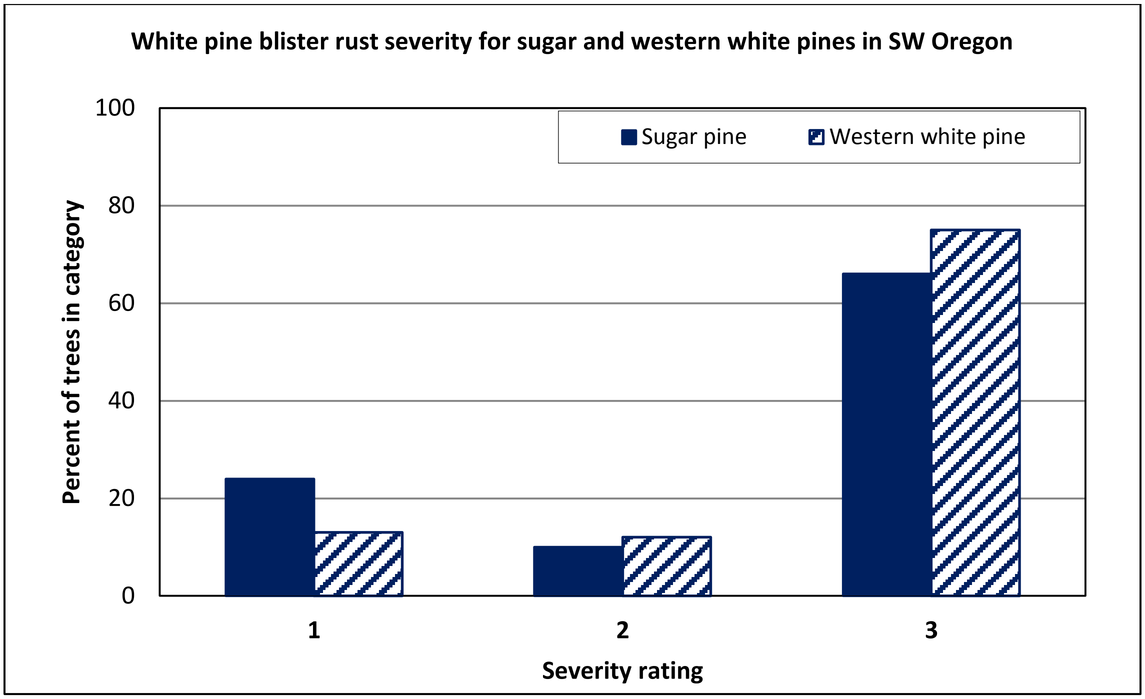


Figure 24. White pine blister rust infection on live trees of all sizes by host and severity rating: Severity 1 = branch cankers greater than 60 cm (24 in) from bole; severity 2 = branch cankers between 15 and 60 cm (6 to 24 in) from the bole; Severity 3 = Branch cankers within 15 cm (6 in) of the bole or bole canker.

Ribes species, alternate hosts of *C. ribicola*, were detected in only seven of the surveyed stands (13 percent) and within those stands in 11 of 70 plots (16 percent). Mean percent *Ribes* spp. cover for the stands with *Ribes* spp. was only 0.4 percent. *Ribes* spp. found in sugar pine survey stands were sticky current (*R. viscosissimum*), red-flowered current (*R. sanguineum*), Lobb's gooseberry (*R. lobbii*) (fig. 25), and shiny-leaf gooseberry (*R. cruentum*).


Figure 25. Flowering *Ribes lobbii*.

Mountain Pine Beetle

Mountain pine beetle-killed sugar pines were encountered in 46 of the 55 survey stands (84 percent) (table 5). Mountain pine beetles were involved in tree killing in 86 percent of the 158 plots with dead sugar pines that had dbhs of 12.7 cm (5.0 in) or greater. Among all dead sugar pine trees of 12.7 cm (5.0 in) dbh or greater, 73 percent had been infested by mountain pine beetles (fig. 26).

Figure 26. Sugar pine mortality caused by mountain pine beetles: Siskiyou Mountains, Southwest Oregon.

Table 5. Mountain pine beetle infestation in 55 randomly selected Southwest Oregon stands with sugar pine components.

Dead tree size category	**Mean number of MPB infested sugar pines per hectare** (infested pines per acre)	**Standard Error** *based on pines per hectare*	**Percent of dead sugar pines in category infested by mountain pine beetles**
Small[1]	0.97 (0.4)	0.75	24.79 (SE = 0.16)
Medium[2]	4.23 (1.7)	1.13	80.87 (SE = 0.07)
Large[3]	2.34 (0.95)	0.50	80.64 (SE = 0.05)
All	7.54 (3.0)	1.77	75.94 (SE=4.79)

[1]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [2]Medium 25.4-50.8 cm (10-20.0 in) dbh; [3]Large $\geq$ 50.9 cm (20 in) dbh

Root Diseases

Armillaria root disease (caused by the fungus *Armillaria ostoyae*) was found on dead and declining sugar pines in four of the 55 survey stands (7 percent). Within these stands, infected sugar pines were detected in 11 of the 32 plots that contained sugar pines (34 percent), and 53 percent of the sugar pine trees in these plots had detectable *A. ostoyae* infections (fig. 27). All dead sugar pines with Armillaria root disease that were larger than 12.7 cm (5.0 in) dbh also exhibited evidence of infestation by mountain pine beetles. In two of the stands where *A. ostoyae*-infected sugar pines were encountered, sugar pine was the only tree species that showed evidence of infection by the fungus. In the other two, ponderosa pines, Douglas-firs, and white firs were also infected. In addition, there were four survey stands in which only white firs were infected by *A. ostoyae* while sugar pines, though present and relatively numerous, were not. Three other root diseases were encountered in survey stands affecting other tree species but never sugar pines. Heterobasidion (Annosus) root disease (caused by *Heterobasidion occidentale* = *H. annosum* S-type) was found in 10 stands affecting white firs. Laminated root rot (caused by *Phellinus weirii*) was found in seven stands affecting Douglas-firs and white firs. Black stain root disease (caused by *Leptographium wageneri*) was found in two stands affecting Douglas-firs.

Figure 27. Mycelial fans of *Armillaria ostoyae*, cause of Armillaria root disease, under the bark of a dying sugar pine.

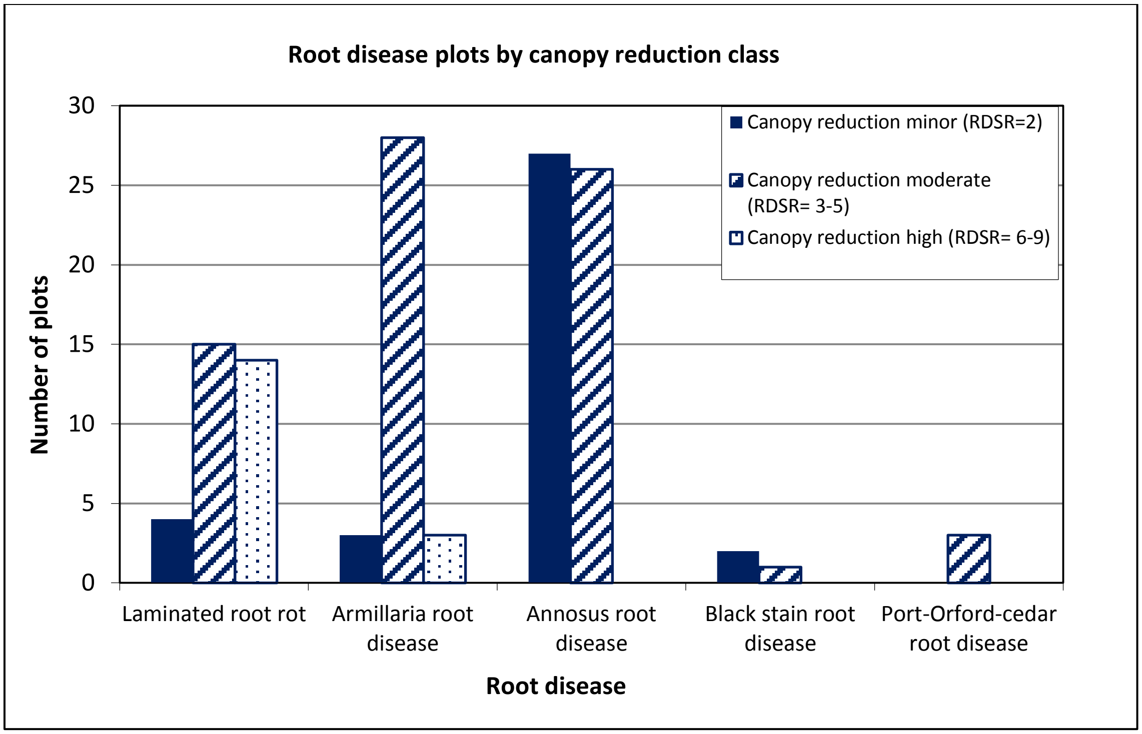


Figure 28. Number of plots by root disease and root disease severity rating (RDSR) for all tree species in both sugar pine and western white pine survey stands.

When all conifer hosts are considered, 48 (43.6 percent) of the 110 sugar pine and western white pine survey stands exhibited occurrence of some level of root disease. Plots with laminated root rot exhibited the highest canopy reductions for all tree species on a stand basis (fig. 28). Moderate canopy reduction was often associated with Armillaria and Annosus root diseases.

Dwarf Mistletoes

Dwarf mistletoes (*Arceuthobium* spp.) are extremely important pathogens in Southwest Oregon.

Table 6. Occurrence and severity of dwarf mistletoe infection on all tree species in 55 randomly selected stands with sugar pine components in Southwest Oregon

Mistletoe Species	**Host Species**	**Number of stands with infected hosts**	**Percent of plots in infested stands with infected hosts**	**Percent of host trees infected in infested plots**	**Average Hawksworth Dwarf Mistletoe Rating* for all hosts in infested plots**
Arceuthobium douglasii	Douglas-fir	10 (18%)	35	76	3.7
A. abietinum f. sp. *concoloris*	White fir	6 (11%)	28	59	2.5
A. tsugense subsp. *tsugense*	Western hemlock	3 (5%)	67	90	3.8
A. campylopodum	Ponderosa pine	2 (4%)	25	71	3.2

* (Hawksworth 1977)

In sugar pine survey stands, dwarf mistletoes were commonly encountered (table 6) and had rather severe impacts on several other conifer species. Nineteen (35 percent) of the 55 sugar pine survey stands exhibited dwarf mistletoe infections on some conifer host. However, no infections by any dwarf mistletoe species were detected on sugar pines in our evaluation.

White pine blister rust and mountain pine beetles were by far the main causes of sugar pine mortality in surveyed stands, with Armillaria root disease playing a role in a few stands. Very minor additional amounts of sugar pine mortality were contributed by wind-throw, stem breaks, or lightning strikes.

Condition of Western White Pines in Natural Stands on Federal Lands in Southwest Oregon-

Locations of the 55 randomly selected natural stands that were intensively surveyed for western white pine condition in this evaluation are shown in Figure 17. The survey stands were well distributed across the federal lands in Southwest Oregon that are within the native range of the species. All of the 55 surveyed stands had western white pine components, and 397 of the total 550 plots in all stands (72 percent) contained one or more western white pines (fig. 29).


Figure 29. Western white pine in the Southwest Oregon Cascades.

Among other tree species in the survey stands, Douglas-fir clearly dominated as the most common and widely distributed. White fir, Shasta red fir (*Abies magnifica* var. *shastensis*), mountain hemlock (*Tsuga mertensiana*), western hemlock, and lodgepole pine (*Pinus contorta*), were also common and widely distributed stand components. Less common and/or widely distributed tree species were, in declining order, Jeffrey pine, Port-Orford-cedar, Pacific yew, Pacific silver fir (*Abies amabalis*), golden chinquapin, Engelmann spruce (*Picea engelmannii*), western redcedar, vine maple (*Acer circinatum*), tanoak, incense-cedar, ponderosa pine, knobcone pine, and subalpine fir (*Abies lasiocarpa*). Sugar pines in small numbers were encountered in 7 (13 percent) of the stands that were chosen specifically for western white pine surveys.

Western white pine survey stands fell into 24 different Plant Associations in 11 Plant Series (Atzet et al. 1996). Appendix table 1 shows the frequency of occurrence in Plant Associations. Twenty percent of survey stands were in the White Fir Series, 17 percent in the Mountain Hemlock Series, 11 percent each in the Western White Pine and Western Hemlock Series, nine percent each in the Pacific Silver Fir and Shasta Red Fir Series, seven percent in the Port-Orford-cedar Series, six percent in the Tanoak Series, four percent each in the Lodgepole Pine and Jeffrey Pine Series, and two percent were in the Western Redcedar Series. Sixteen western white pine stands (29 percent) occurred on ultramaphic (serpentine or peridotite) soil types (fig. 30).

Figure 30. Western white pines on a serpentine soil in the Siskiyou Mountains, Southwest Oregon.

Twenty-five of the western white pine survey stands (45 percent) had not had harvest entries prior to survey. The remaining 30 (55 percent) had experienced some level of individual tree selection or small group selection harvest. Eighteen of the stands (33 percent) showed readily detectable evidence of past wind-throw events, and 12 (22 percent) had experienced past fires of sufficient magnitude to cause easily identified fire scars on a substantial number of large trees.

On average for all trees (living and dead) in surveyed stands, western white pines made up 18 percent of the stocking (trees per hectare) (table 7, fig. 31) and 15 percent of the basal area (m^2 per hectare) (table 8, fig. 32). Of the western white pine trees, 17 percent, accounting for 50 percent of the species' basal area, was dead. There was also an average of 4.1 western white pine stumps containing 1.1 m^2 of basal area per hectare (4.8 ft^2 per acre).

Table 7. Mean numbers of trees/hectare (trees per acre) in 55 randomly selected natural stands with western white pine components surveyed in Southwest Oregon.			
Species/Category	**Stems per hectare** (stems per acre)	**Standard Error** *Based on stems per hectare*	**Range in stems per hectare (stems per acre)**
Western White Pine			
Live Seedlings[1]	400.3 (162.0)	76.4	0-3088.6 (0-1250.0)
Live Saplings[2]	257.9 (104.4)	65.4	0-2470.9 (0-1000.0)
Live Small[3]	19.6 (7.9)	5.1	0-151.0 (0-61.1)
Live Medium[4]	9.2 (3.7)	1.8	0-50.3 (0-20.4)
Live Large[5]	3.6 (1.5)	0.5	0-20.3 (0-8.2)
All Live	699.5 (283.1)	135.8	0-5614.7 (0-2272.3)
Dead Seedlings[1]	18.0 (7.3)	5.9	0-271.8 (0-110.0)
Dead Saplings[2]	87.6 (35.5)	25.0	0-1186.0 (0-480.1)
Dead Small[3]	24.2 (9.8)	6.9	0-274.5 (0-111.1)
Dead Medium[4]	9.4 (3.8)	1.8	0-63.3 (0-25.6)
Dead Large[5]	4.4 (1.8)	0.7	0-25.9 (0-10.5)
All Dead	145.0 (58.7)	36.2	0-1775.6 (0-718.6)
Stumps	4.1 (1.7)	1.1	0-46.2 (0-18.7)
All Other Tree Species			
Live Seedlings[1]	2326.7 (941.6)	419.0	0-20261.4 (0-8199.8)
Live Saplings[2]	1073.7 (434.5)	139.6	24.7-4793.5 (10.0-1939.9
Live Small[3]/Medium[4]/Large[5]	321.1 (129.9)	32.6	16.7-1414.3 (6.8-572.4)
All Live	3722.4 (1506.5)	489.9	115.6-23180.1 (46.8-9381.0)
Dead Seedlings	14.4 (5.8)	4.1	0-173.0 (0-70.0)
Dead Saplings	93.9 (38.0)	24.6	0-963.6 (0-390.0)
Dead Small[3]/Medium[4]/Large[5]	103.1 (41.7)	33.2	0-1829.9 (0-740.6)
All Dead	211.4 (85.6)	40.9	0-1854.6 (0-750.6)
Stumps	14.2 (5.7)	2.8	0-80.5 (0-32.6)

[1]Seedlings = trees less than 1.4 m tall (4.5 ft) (no dbh); [2]Saplings = trees with dbh of 0.1 to 12.6 cm (0.1 to 4.9 in); [3]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [4]Medium 25.4-50.8 cm (10-20.0 in) dbh; [5]Large $\geq$ 50.9 cm (20 in) dbh

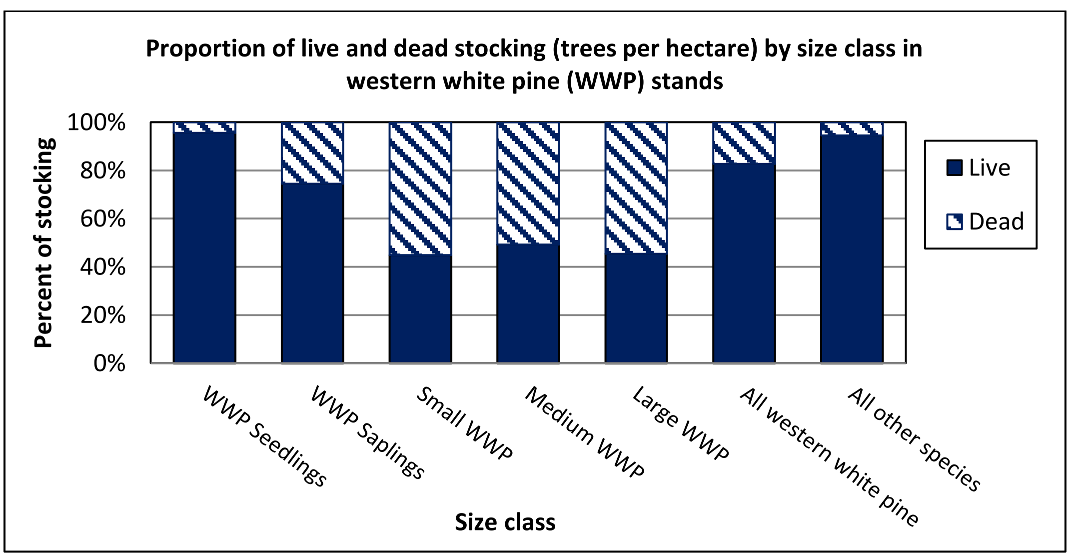


Figure 31. Proportion of live and dead stocking (trees per hectare) by size class in western white pine stands.

Table 8. Mean basal area in 55 randomly selected natural stands with western white pine components surveyed in Southwest Oregon			
Species/Category	**Basal Area** in m² per hectare (ft² per acre)	**Standard Error** *based on m² per hectare*	**Range in m² per hectare (ft² per acre)**
Western White Pine			
Live Small[1]	0.5 (2.2)	0.1	0-3.2 (0-13.9)
Live Medium[2]	1.1 (4.8)	0.2	0-7.3 (0-31.8)
Live Large[3]	1.6 (7.0)	0.2	0-6.9 (0-30.1)
All Live	3.3 (14.4)	0.4	0-11.9 (9-51.8)
Dead Small[1]	0.6 (2.6)	0.2	0-7.3 (0-31.8)
Dead Medium[2]	1.1 (4.8)	0.2	0-8.7 (0-37.9)
Dead Large[3]	1.5 (6.5)	0.2	0-7.8 (0-34.0)
All Dead	3.3 (14.4)	0.4	0-17.4 (0-75.8)
Stumps	1.1 (4.8)	0.2	0-8.3 (0-36.2)
Other Tree Species			
Live (Small/Medium/Large)	30.4 (132.4)	2.5	2.3-68.8 (10.0-299.7)
Dead (Small/Medium/Large)	5.9 (25.7)	0.6	0-18.4 (0-80.2)
Stumps	5.1 (22.2)	0.9	0-30.3 (0-132.0)

[1]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [2]Medium 25.4-50.8 cm (10-20.0 in) dbh; [3]Large ≥ 50.9 cm (20 in) dbh

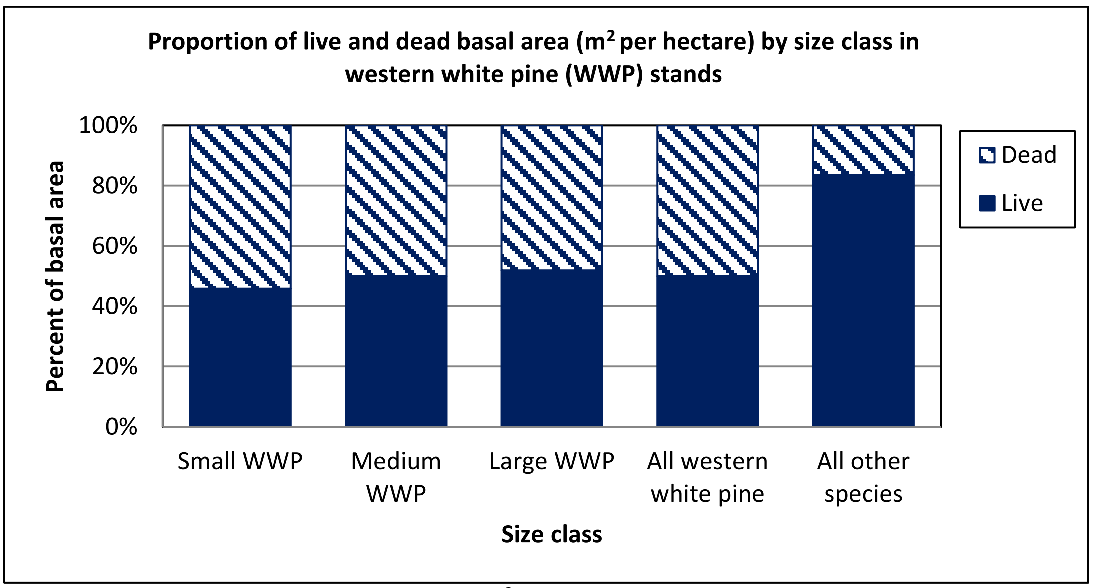


Figure 32. Proportion of live and dead basal area (m^2 per hectare) by size class in western white pine stands.

White Pine Blister Rust

White pine blister rust was detected on western white pines in 51 of the 55 survey stands (93 percent) and was identified in 266 of the 397 plots that contained western white pines (67 percent). Amount of blister rust detected varied considerably among stands and plots. On average for all surveyed stands, 30 percent of all western white pine trees had detectable *C. ribicola* infections (table 9): 29 percent of all live western white pines and 55 percent of all dead western white pines.

Table 9. Mean number of white pine blister rust-affected western white pines (WWP) per hectare (trees per acre) in 55 randomly selected Southwest Oregon natural stands with western white pine components.

Category	**Mean number of infected WWP per hectare** (infected WWP per acre)	**Standard Error** *(based on WWP per hectare)*	**Percent of WWP in category infected**
Live			
Live Seedlings[1]	38.19 (15.46)	7.47	10.57 (SE = 2)
Live Saplings[2]	94.79 (38.36)	20.46	43.29 (SE = 4)
Live Small[3]	10.78 (4.36)	2.60	69.39 (SE = 7)
Live Medium[4]	6.06 (2.45)	1.41	56.85 (SE = 7)
Live Large[5]	2.47 (1.00)	0.48	70.32 (SE = 6)
All Live	152.29 (61.63)	28	28.74 SE = 0.2
Dead			
Dead Seedlings[1]	17.07 (6.91)	5.44	97.17 (SE=2)
Dead Saplings[2]	76.37 (30.91)	21.05	87.67 (SE=5)
Dead Small[3]	7.00 (2.83)	3.35	28.41 (SE=9)
Dead Medium[4]	2.46 (1.00)	0.87	21.13 (SE=6)
Dead Large[5]	0.61 (0.25)	0.21	15.35 (SE=4)
All Dead	104.84 (42.43)	26.82	55.5 (SE = 5)
All	**265.94 (107.63)**	**51.24**	**30.07 (SE = 3)**

[1]Seedlings = trees less than 1.4 m tall (4.5 ft) (no dbh); [2]Saplings = trees with dbh of 0.1 to 12.6 cm (0.1 to 4.9 in);
[3]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [4]Medium 25.4-50.8 cm (10-20.0 in) dbh; [5]Large $\geq$ 50.9 cm (20 in) dbh

Mortality associated with white pine blister rust was extremely high in smaller size classes of western white pine (fig. 33). Ninety-seven and 88 percent of the mortality in seedling and sapling western white pine, respectively, was associated with white pine blister rust infections. Twenty-seven percent of dead western white pines in the small tree category exhibited apparently lethal white pine blister rust cankers as well. In the medium and large sized western white pines, detectable blister rust infections, though occurring on 21 and 15 percent of the dead hosts respectively, were almost entirely on branches and tops and did not appear to contribute directly to death of entire trees. As with sugar pines, most of the live-infected sapling and pole-sized western white pines exhibited potentially lethal infections (fig. 24).

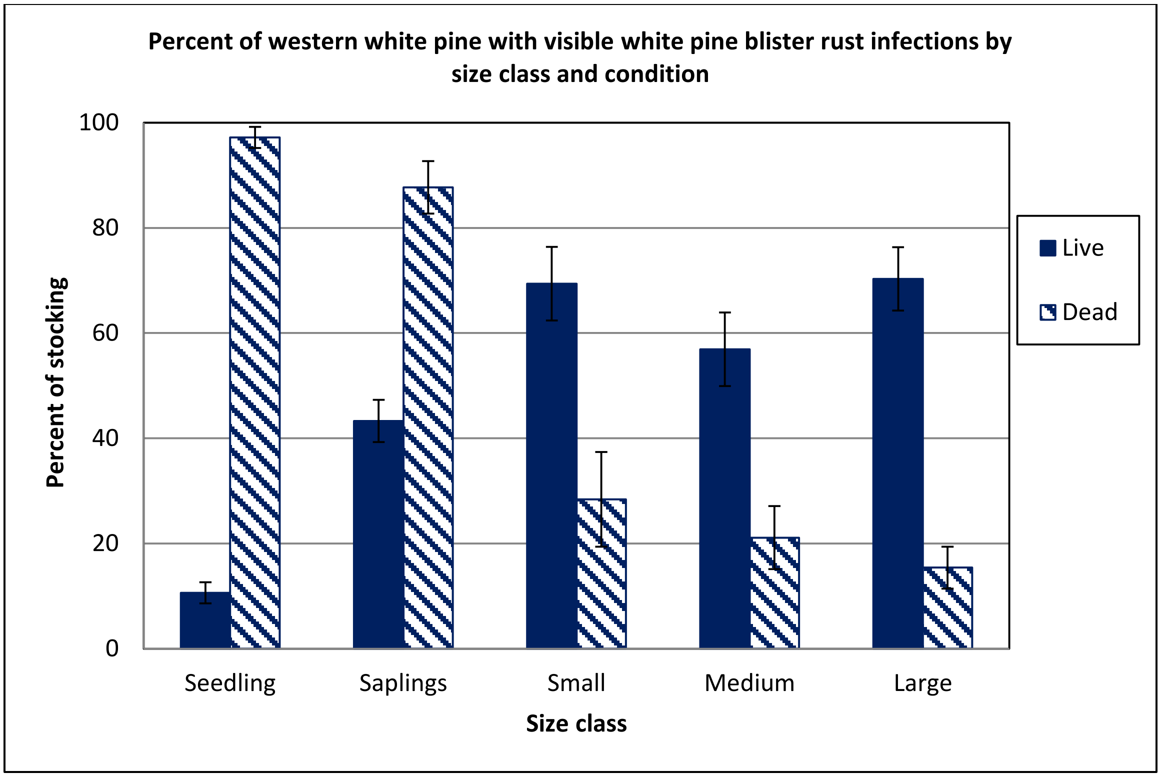


Figure 33. Percent of western white pine with visible white pine blister rust infections by size class and condition. Bars indicate standard errors.

Ribes species were detected in 17 of the surveyed stands (31 percent) and within these stands in 52 of 170 plots (31 percent). Mean percent *Ribes* spp. cover for the stands with *Ribes* spp. was 6 percent. The same species of *Ribes* were noted in western white as sugar pine survey stands with the addition of squaw currant (*R. cereum*) (fig. 34), swamp gooseberry (*R. lacustre*) and stink currant (*R. bracteosum*).

Figure 34. *Ribes cereum* in close association with a *C. ribicola*-infected western white pine, Southwest Oregon Cascades.

Mountain Pine Beetle

Mountain pine beetle-killed western white pines were encountered in 46 of the 55 survey stands (84 percent), and mountain pine beetles were involved in tree killing in 82 percent of the 150 plots that contained dead western white pines with dbhs of 12.7 cm (5.0 in) or greater. Among all dead western white pine trees of 12.7 cm (5.0 in) or greater dbh, 69 percent had been infested by mountain pine beetles. Table 10 shows the amount of infestation by western white pine size class.

Table 10. Mountain pine beetle infestation in 55 randomly selected Southwest Oregon stands with western white pine components

Dead tree size category	**Mean number of MPB infested western white pines per hectare** (infested pines per acre)	**Standard Error** *based on infested western white pine per hectare*	**Percent of dead western white pines in category infested by mountain pine beetles**
Small[1]	4.39 (1.78)	1.39	18.13 (SE = 0.16)
Medium[2]	8.68 (3.51)	1.75	92.24 (SE = 0.07)
Large[3]	3.76 (1.52)	0.67	84.49 (SE = 0.05)
All	16.83 (6.81)	2.80	69.25 (SE = 0.05)

[1]Small 12.7-25.3 cm (5.0-9.9 in) dbh; [2]Medium 25.4-50.8 cm (10-20.0 in) dbh; [3]Large ≥ 50.9 cm (20 in) dbh

Other Bark Beetles

Pine engraver beetles, *Ips* spp., were found on western white pines in 14 of the 55 survey stands (25 percent) and had constructed galleries on trees in 27 of the 122 plots that contained western white pines in these stands (22 percent). Among all dead western white pine trees of 12.7 cm (5.0 in) or greater dbh in these stands, 27 percent exhibited galleries of pine engravers. In some cases, pine engravers were found on western white pines that were also infested by mountain pine beetles. In such situations, pine engravers appeared to be playing a secondary role. However, pine engraver beetles were prominent as the main and often the only bark beetles detected on dead western white pines on sites with ultramafic soils in the Siskiyou Mountains.

Root Diseases

In the western white pine survey stands, five root diseases were encountered. Although other tree species frequently exhibited substantial amounts of infection by root pathogens, in our survey, almost no root disease-affected western white pines were observed. Heterobasidion (Annosus) root disease was encountered in 17 survey stands affecting white fir, Shasta red fir, Pacific silver fir, western hemlock, and mountain hemlock. Black stain root disease was found in one stand affecting Douglas-fir. Laminated root rot was found in four stands affecting mountain hemlock, Douglas-fir, white fir, and Pacific silver fir. Port-Orford-cedar root disease (caused by *Phytophthora lateralis*) was found in two stands affecting only Port-Orford-cedar. Armillaria root disease was found in 14 stands affecting mainly white fir, Shasta red fir, Pacific silver fir, mountain hemlock, and Douglas-fir. It was the only root disease found on western white pines in the survey, but was identified on only two sample trees of this species in one stand. Outside of this stand, though present and often numerous in stands where other tree species were infected by *A. ostoyae*, western white pines exhibited no infection. Figure 28 summarizes canopy reduction impacts caused by root diseases on all trees in both western white pine and sugar pine survey stands.

Dwarf Mistletoes

As with the sugar pine survey stands, the western white pine stands examined in this evaluation exhibited substantial amounts of dwarf mistletoe infection on several conifer species (table 11). Twenty-eight (51 percent) of the western white pine survey stands had detectable dwarf mistletoe infections on one or more conifer hosts.

Table 11. Occurrence and severity of dwarf mistletoe infection on all tree species in 55 randomly selected stands with western white pine components in Southwest Oregon

Mistletoe Species	**Host Species**	**Number of stands with infected hosts** (percent of all stands)	**Percent of plots in infested stands with infected hosts**	**Percent of host trees infected in infested plots**	**Average Hawksworth Dwarf Mistletoe Rating* for all hosts in infested plots**
A. americanum	Lodgepole pine	4 (7%)	22	44	1.7
A. douglasii	Douglas-fir	4 (7%)	32	58	3.6
A. tsugense subsp. *tsugense*	Western hemlock	8 (14%)	34	89	4.7
A. tsugense subsp. *mertensianae*	Mountain hemlock	8 (14%)	52	97	5.2
A. tsugense subsp. *mertensianae***	Western white pine	2 (4%)	30	100	3.0
A. monticola	Western white pine	4 (7%)	42	84	2.5
A. campylopodum	Jeffrey pine	4 (7%)	17	33	2.7
A. siskiyouense	Knobcone pine	2 (4%)	40	100	4.9
A. abietinum f. sp. *concoloris*	White fir	1 (2%)	60	89	5.1
A. abietinum f. sp. *concoloris*	Pacific silver fir	1 (2%)	50	78	4.9

* (Hawksworth 1977)

Unlike the case with sugar pines, western white pines were themselves infected by dwarf mistletoe in some stands. Infections were identified on western white pines in six of the 55 survey stands (11 percent). Two species of dwarf mistletoe were found on western white pines. Mountain hemlock dwarf mistletoe (*Arceuthobium tsugense* subsp. *mertensianae*) was found in two stands (4 percent of all survey stands) infecting western white pines that were growing in close association with mountain hemlocks that had severe *A. tsugense* subsp.

Figure 35. Male plants of *Arceuthobium tsugense* subsp. *mertensianae* on western white pine.

mertensianae infections (fig. 35). In these stands, 30 percent of the plots contained dwarf mistletoe-infected western white pines and all pine hosts in these plots were infected. These stands were located at relatively high elevations in the Cascade Mountains at the eastern edge of the survey area. Western white pine dwarf mistletoe (*A. monticola*) was found on western white pines in four stands (seven percent of all survey stands). White pine hosts infected by western white pine dwarf mistletoe were found only in stands growing on ultramafic soils in the Siskiyou Mountains, but they were rather common on this kind of site. In survey stands with *A. monticola* on western white pines, 42 percent of the plots contained dwarf mistletoe-infected pines, and in these plots, 84 percent of the western white pine trees were infected. Neither species of dwarf mistletoe encountered in our survey appeared to be major contributors by themselves to western white pine mortality though they undoubtedly affected host growth and vitality in cases of heavy infections and may have functioned as predisposing agents for bark beetles.

White pine blister rust, mountain pine beetles, and pine engraver beetles were by far the main mortality agents of western white pines in surveyed stands (fig. 36). Stem break was a very minor contributor to mortality.

Figure 36. Mountain pine beetles and white pine blister rust contribute to mortality and damage, western white pine, Siskiyou Mountains, Southwest Oregon.

Influence of Site and Stand Factors on Diseases and Insects of Sugar and Western White Pines in Southwest Oregon

Comparisons of stand level white pine blister rust severity data for all survey stands indicated that site and stand factors examined in this evaluation appeared to influence the disease in Southwest Oregon.

<u>Plant Series</u>

Although severely affected stands were encountered in all Plant Series, the Douglas-fir (Psme), Tanoak (Lide), and Western Hemlock (Tshe) Series tended to have lower proportions of severely diseased stands than the Mountain Hemlock (Tsme), Western White Pine (Pimo), Port-Orford-cedar (Chla), Western Redcedar (Thpl), or any of the true fir Plant Series (Abco, Abam, Abmas) (figs. 37 and 38). Jeffrey Pine (Pije) and Lodgepole Pine (Pico) Plant Series had equal numbers of stands in the light to moderate and severe categories; however the number of stands sampled in those Series was low. The six stands where white pine blister rust was not detected at all occurred in Douglas-fir, Western Hemlock, Mountain Hemlock, White Fir and Shasta Red Fir Plant Series. The Plant Association for one western white pine stand was impossible to determine.

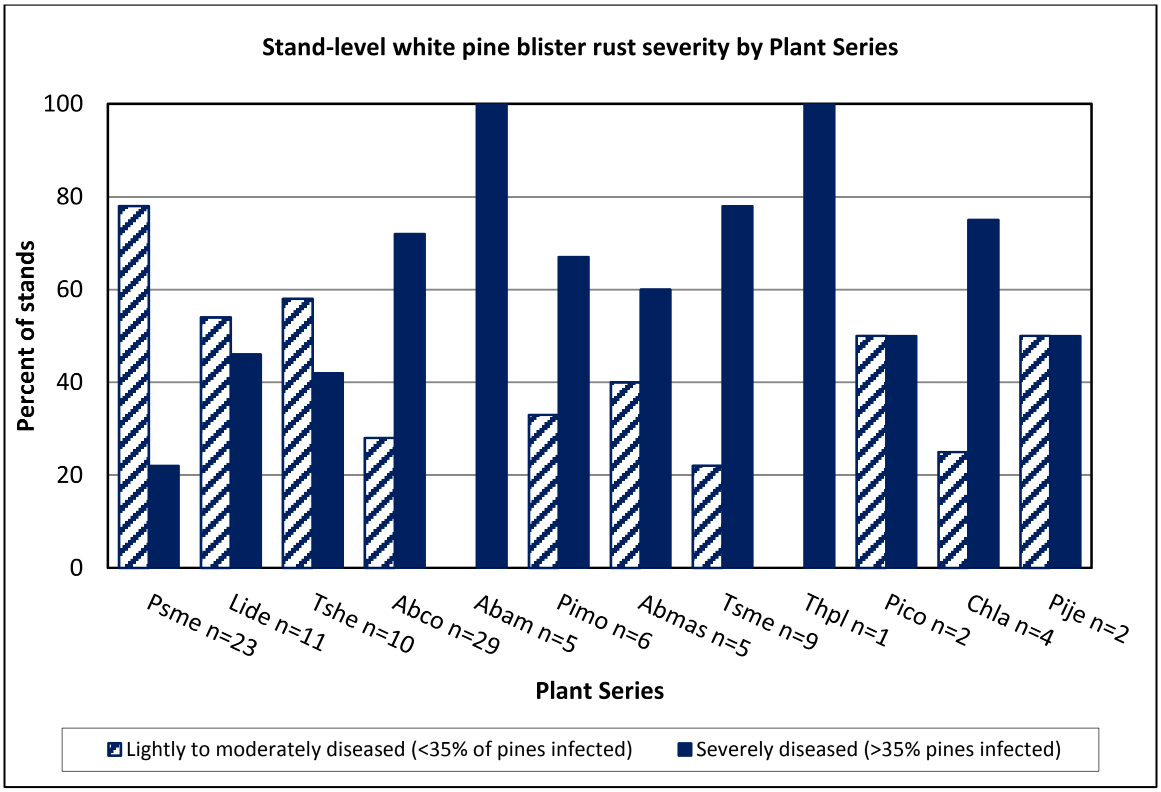


Figure 37. Percent of stands that are lightly to moderately versus severely impacted by white pine blister rust by Plant Series.

Figure 38. Western white pines growing in a laminated root rot pocket, Mountain Hemlock Plant Series, Southwest Oregon Cascades.

Aspect

While not statistically different (Fisher's Exact Test) from east, south, or west aspects, flat areas and north aspects tended to show higher proportions of stands with five-needle pine components that were severely affected by white pine blister rust (fig. 39).

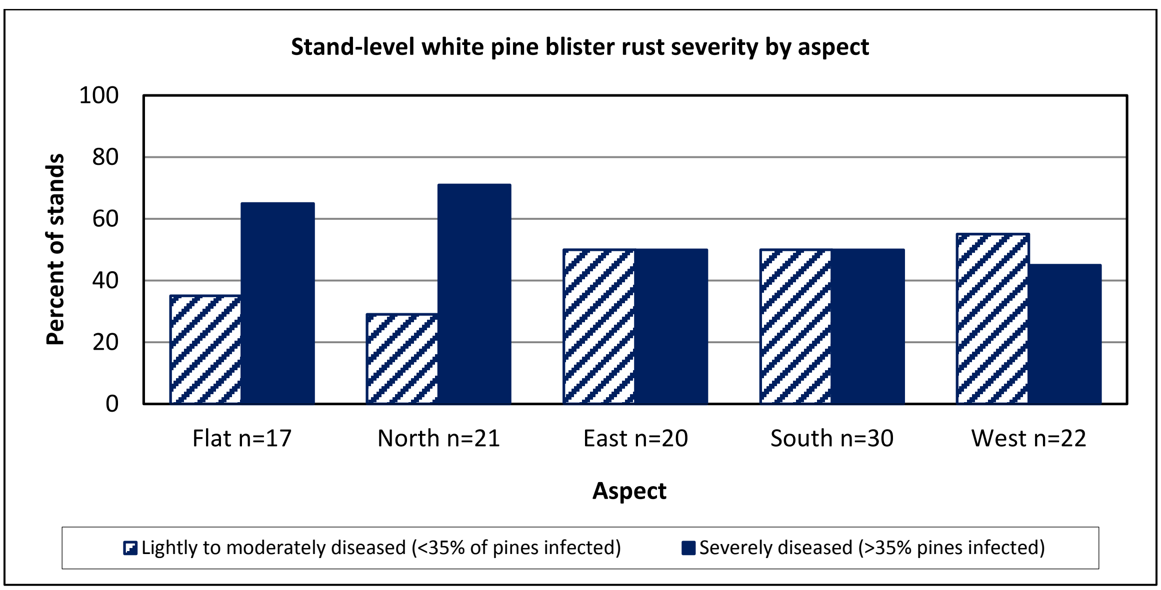


Figure 39. Percent of stands that were lightly to moderately versus severely impacted by white pine blister rust by average aspect observed for the stand.

Elevation

The proportion of stands with five-needle pine components exhibiting severe white pine blister rust infections tended to increase with increasing elevation (fig. 40).

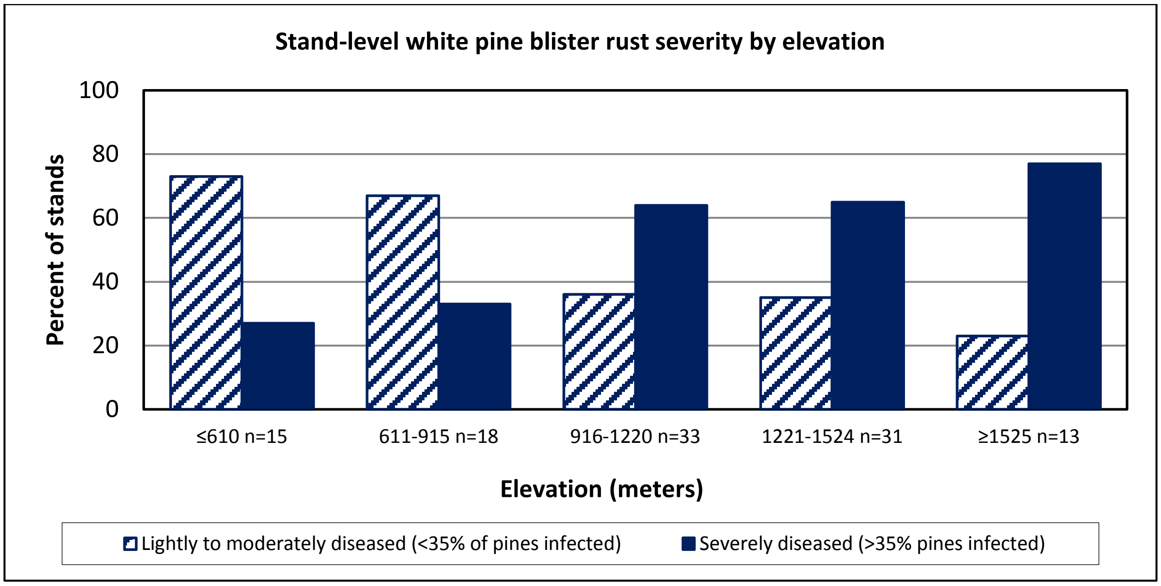


Figure 40. Percent of stands that are lightly to moderately versus severely impacted by white pine blister rust by average elevation observed for the stand.

Slope

The proportion of stands with five-needle pine components showing severe levels of white pine blister rust infection tended to decrease with increasing average percent slope and was highest on flat and very gently sloping areas (figs. 41 and 42).

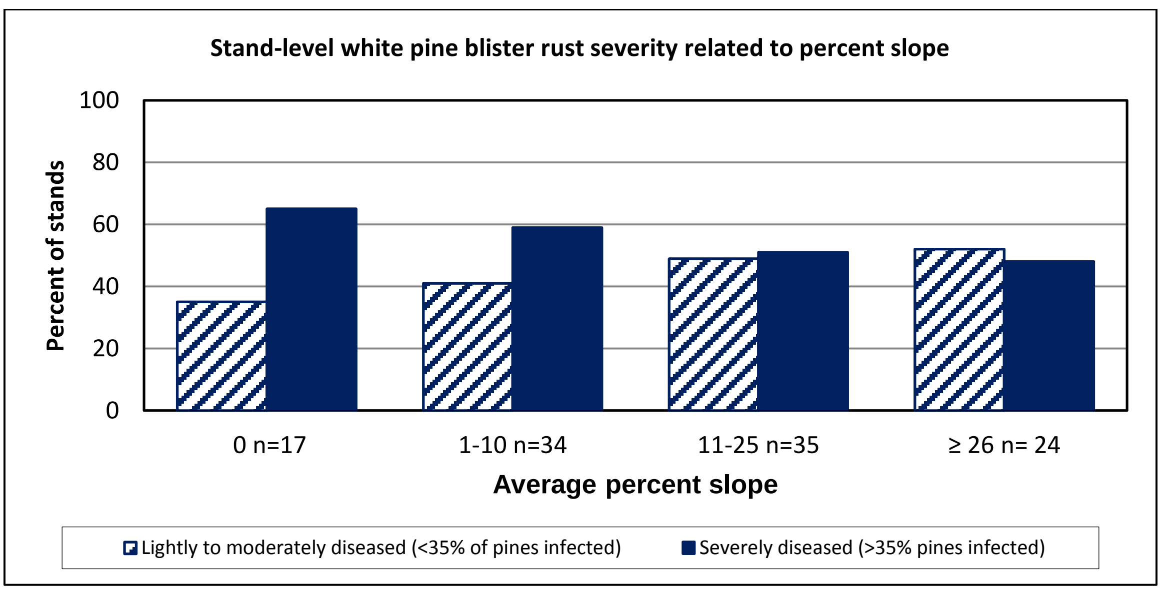


Figure 41. Percent of stands that are lightly to moderately versus severely impacted by white pine blister rust by average percent slope observed for the stand.

Figure 42. Lethal bole infection of western white pine on a flat site in the Southwest Oregon Cascades.

Topographical Position

Mid-slope positions tended to show a lower proportion of stands with severe white pine blister rust in their five-needle pine components than lower third or upper third slope positions (fig. 43).

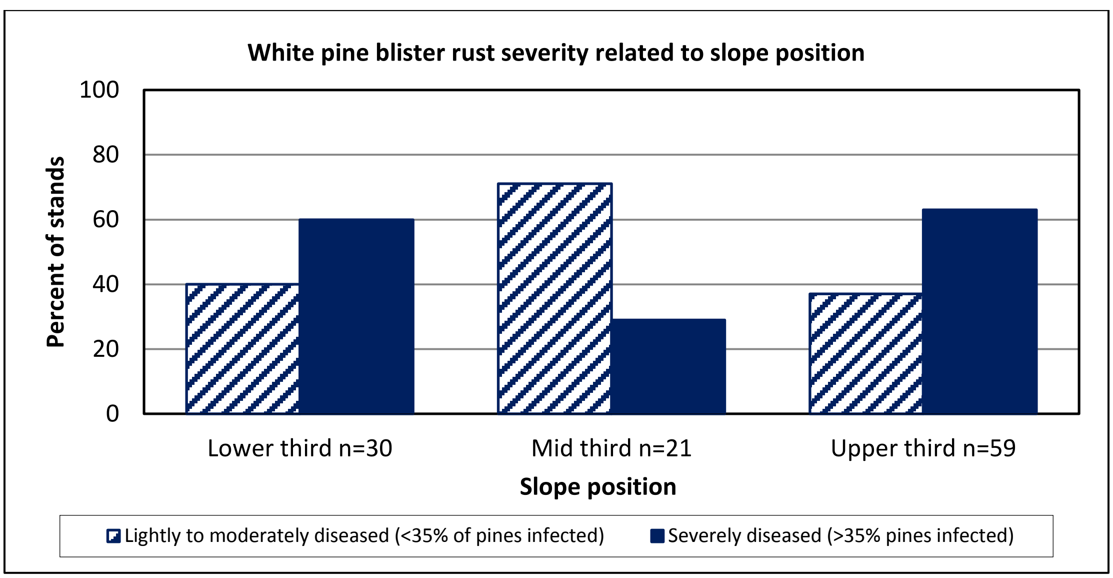


Figure 43. Percent of stands that are lightly to moderately versus severely impacted by white pine blister rust by average slope position observed for the stand.

<u>*Ribes* spp. Occurrence in Survey Plots</u>

Though differences were not statistically significant (Fishers's Exact Test), the proportion of stands with severe levels of white pine blister rust in their five-needle pine components did show a tendency to be greater where *Ribes* spp. occurrence was noted in survey plots than in stands where these alternate hosts were not encountered (fig. 44). Nonetheless, there were substantial proportions of severely infected stands in both groups (fig. 45).

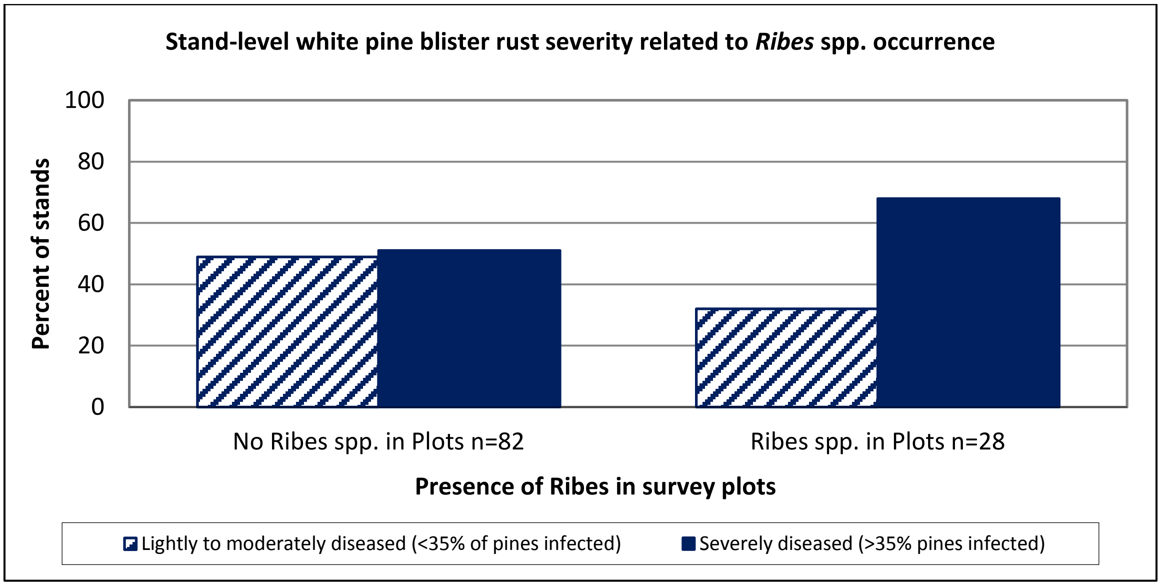


Figure 44. Percent of stands that are lightly to moderately versus severely impacted by white pine blister rust by presence or absence of *Ribes* spp. on survey plots.

Figure 45. *Cronartium ribicola*-infected *Ribes bracteosum* at the Champion Mine site, Southwest Oregon Cascades. Photo courtesy of G. Barnes, USFS retired, Dorena Genetics Resource Center.

Stand Density

Bark beetle infestation of five-needle pines in sampled Southwest Oregon stands appeared to be strongly influenced by stand density. There was evidence of significantly higher basal area (in m² per hectare (ft^2 per acre)) for survey plots with mountain pine beetle infested sugar pines ($p<0.0001$ Wilcoxon signed-rank test) than for plots in the same stands with live sugar pines and no infestation (table 12 and Appendix tables 2 and 3). There was less significant but still convincing evidence ($p<0.006$ Wilcoxon signed-rank test) of that same relationship for plots with infested versus uninfested western white pines. Basal area variability was greater in western white pine than sugar pine survey stands.

Table 12. Mean basal area of sugar pine and western white pine survey plots with and without mountain pine beetle-infested pines

	Ave. BA in m² per hectare (ft^2 per acre) for plots that contained five-needle pines but no MPB infestations	**Ave. BA in m² per hectare (ft^2 per acre) for plots with MPB-infested five-needle pines**
Sugar pine survey stands	38.8 (169.0)	55.1 (240.0)
Western white pine survey stands	37.2 (162.0)	55.4 (241.3)

Where pine engraver beetles were primary killers of western white pines on ultramafic soils in the Siskiyou Mountains, they also showed a strong tendency to infest hosts in the denser portions of stands (Appendix table 4). The diameters of sugar and western white pines infested by mountain pine beetles averaged slightly higher than those of uninfested sugar and western white pines in the same stands (Appendix tables 2 and 3) and infested pines were most numerous in the larger host size classes (tables 4 and 8). In contrast, pine engraver beetles infesting hosts by themselves, appeared to show a preference for or were more successful on smaller trees (Appendix table 4). In comparison to other host pine species that occurred in the same sample stands with them, sugar pines showed a much higher proportion of bark beetle-infested trees than did ponderosa pines (Appendix table 5), and western white pines showed a somewhat higher proportion of trees infested by mountain pine beetles than did lodgepole pines (Appendix table 6).

Detected Wildlife Use of Five-Needle Pines and Other Tree Species

In surveyed stands, both sugar and western white pines appeared to provide significant excavation and cavity nesting habitat and, along with Douglas-firs and white firs, were the most prominent of tree species in this regard (tables 13 and 14) (fig. 46). Excavations were especially common in large-sized dead five-needle pines. Most excavations noted in surveys appeared to be nesting cavities.

Figure 46. Avian excavation in western white pine snag, Cascade Mountains, Southwest Oregon.

Table 13. Occurrence of wildlife excavations by tree species, dbh, and condition in 55 stands with sugar pine components evaluated in Southwest Oregon (expressed as percent of the 231 nest cavities detected)

Tree species	**Live**			**Dead**			**All**
	< 50 cm dbh (<19.9 in)	50-100 cm dbh (20-39.9 in)	> 100 cm dbh (>40 in)	<50 cm dbh (<19.9 in)	50-100 cm dbh (20-39.9 in)	> 100 cm dbh (>40 in)	
Ponderosa pine	0	0	0	0.9	3.9	1.7	6.5
Douglas-fir	0.4	2.2	1.7	3.5	11.3	7.4	26.5
Sugar pine	0	0	0.9	3.9	20.3	15.1	40.2
Golden chinquapin	0.4	0	0	1.3	0	0	1.7
Pacific madrone	0	1.3	0	0	0	0	1.3
White fir	0	0	0	4.3	3.0	0	7.3
Incense-cedar	0	1.3	3.5	0	1.7	0.4	6.9
Western hemlock	0	0.4	0	0	0.4	0	0.8
Western redcedar	0.4	3.5	0	0	0	0.4	4.3
California black oak	0	0.9	0	0.4	1.7	0	3.0
Tanoak	0	0.4	0	0	0	0	0.4
Knobcone pine	0	0	0	0.4	0	0	0.4
Unidentifiable	0	0	0	0	0.4	0	0.4

Table 14. Occurrence of wildlife excavations by tree species, dbh, and condition in 55 stands with western white pine components evaluated in Southwest Oregon (expressed as percent of the 145 nest cavities detected)							
Tree species	**Live**			**Dead**			**All**
	< 50 cm dbh (<19.9 in)	50-100 cm dbh (20-39.9 in)	> 100 cm dbh (>40 in)	<50 cm dbh (<19.9 in)	50-100 cm dbh (20-39.9 in)	> 100 cm dbh (>40 in)	
Lodgepole pine	0.7	0	0	2.1	0.7	0	3.5
Douglas-fir	1.4	2.1	5.5	4.8	9.0	6.2	29.0
Western white pine	0	0	1.4	6.2	14.5	2.1	24.2
White fir	0.7	2.8	0	3.4	15.2	0.7	22.8
Mountain hemlock	0	0.7	0	2.8	0.7	0	4.2
Shasta red fir	0	0	0	0	4.1	0.7	4.8
Port-Orford-cedar	0	1.4	0	0	1.4	0	2.8
Western hemlock	0.7	1.4	0	1.4	1.4	0	4.9
Incense-cedar	0	0.7	0	0	1.4	0	2.1
Sugar pine	0	0	0	0	1.4	0	1.4
Pacific silver fir	0	0	0	0.7	0	0	0.7
Western redcedar	0	0.7	0	0	0	0	0.7

DISCUSSION

The FIA and CVS inventory data collected from systematically distributed plots arrayed across all land ownerships represent a good source of information on landscape-level occurrence of five-needle pines larger than 2.5 cm (1.0 in) dbh and on recently dead versus live trees in these diameter classes. While the data show that five-needle pines are widely distributed in much of Oregon and Washington, they indicate that this is especially true for Southwest Oregon where twice as many plots contain these species as the average for the entire Pacific Northwest. The relative amount of sugar pine is particularly great. Though sugar pines occur in the Oregon Cascades as far north as the Mt Hood National Forest and are common east of the Cascades in parts of central and southern Oregon, it is clear that sugar pines are particularly important in Southwest Oregon where they occur in a much greater proportion of plots.

Stand-level data on causes of damage and mortality from our intensive surveys on federal lands cannot be directly compared with data from the permanent inventory plots. FIA and CVS data are collected across all ownerships and the inventory data query employed did not differentiate among ownership types (private or other ownerships versus federal). The FIA and CVS plot data used came from any plots where five-needle pines occurred so information from trees in plantations is grouped with information from trees in natural stands. Our stand-level data was collected only in natural stands. Trees of all sizes were assessed in our intensive stand-level survey data. Severity and cause of damage or mortality were not recorded on trees less than 2.5 cm (1.0 in) dbh in the FIA and CVS permanent inventory plots. Roots of dead and dying trees were routinely excavated and examined and samples of bark were removed from boles on dead plot trees during our stand-level surveys; however, to preserve the natural process of falldown, dead and dying trees in permanent CVS and FIA plots were not examined in these ways. Thus, detailed evaluations of dead and dying tagged plot trees were limited. Differences in the level of experience of those identifying causes of damage and mortality on permanent plots versus the intensive stand-level surveys may also account for some differences in results.

Our stand-level survey data indicate that in Southwest Oregon, both sugar pines and western white pines occur as components in diverse, mixed stands with a substantial number of other tree species. As expected, sugar pines were more commonly encountered in our surveys at low and moderate elevations in generally warmer Douglas-fir, White Fir, Tanoak, and Western Hemlock Plant Series. Western white pines were found in a greater variety of Plant Series than sugar pines due at least in part to their occurrence over a wider range of elevations and their more common occurrence on ultramafic soils. They were most frequently encountered in the White Fir, Shasta Red Fir, Pacific Silver Fir, Mountain Hemlock, Western Hemlock, and Western White Pine Plant Series. Plant Associations where western white pines occurred had generally lower average temperatures than those occupied by sugar pines.

Sugar pines tended to occur as minor stand components. However, they often included the largest or among the largest trees in stands and accounted for considerable basal area. Among live sugar pine sample trees in our basal area plots, 75 percent were 20 inches dbh or larger and 50 percent were 30 inches dbh or greater. Mature sugar pines were commonly distributed through stands as widely scattered large individuals or small groups of two or three large trees. Western white pines made up greater proportions of stocking in survey stands where they occurred and tended to be present in larger groups, though still with scattered distributions. As reflected by basal area, western white pine size relative to that of other species in the stands tended to be considerably lower than for sugar pines. Among live sample trees in our basal area plots, 48 percent of the western white pines were 20 inches dbh or greater with 18 percent of the western white pine trees 30 inches dbh or greater.

Regeneration of both sugar and western white pines was substantial and widely distributed in our survey stands though often not in good condition. Apparently, seed production in Southwest Oregon remains ample for both species in spite of top mortality and live crown sizes diminished due to white pine blister rust infections on many mature trees. Also, seeds of both five-needle pines evidently germinate well and seedlings begin to grow even in relatively dense stands where exposure to sunlight is somewhat limited. Both sugar pine and western white pine are classified as seral species but are initially more tolerant of shade than ponderosa pine (Burns and Honkala 1990). Western white pine is more tolerant than sugar pine and is rated as only slightly less tolerant than Douglas-fir. Both sugar and western white pines become increasingly less shade tolerant with age. Thus, they may become established under a certain amount of shade but are unlikely to grow well and become dominant unless released. In our survey stands, saplings of sugar and western white pines growing in dense stands or in portions of stands where they were overtopped tended to be noticeably spindly and to have thin crowns. Even in the absence of infection by white pine blister rust, their futures seem tenuous if not eventually exposed to more sunlight through management treatments or natural disturbance events.

In Southwest Oregon, indications of past disturbance are commonly associated with occurrence of both sugar pines and western white pines in natural stands. In our surveys, evidence of considerable past windthrow and many past fires was found in stands with components of either species, both being more frequent in stands with sugar pines than stands with western white pines. In the stands with evidence of past windthrow, other tree species (especially true firs hemlocks and Douglas-firs) were observed to be much more commonly affected by wind than the sugar or western white pines.

Both five-needle pine species had been harvested extensively in recent decades in our survey stands. Single tree or small group selections were common treatments. Harvest levels (both in terms of numbers and sizes of trees cut) were higher for sugar and western white pines than for other tree species in the same stands. On a percentage basis, there were 2.4 times as many sugar pine stumps representing 1.5 times as much basal area as those of other tree species and 1.2 times as many western white pine stumps representing 1.7 times as much basal area as those of other tree species in the same surveyed stands. Sugar and western white pines may have been preferentially harvested because of their commercial values. It is known that in the past there was a high propensity to cut sugar pines in particular because of their superior quality and value. However, a substantial number of five-needle pine stumps encountered in our surveys showed evidence that they were cut after the trees were already dead (for example, sapwood that was completely colonized by blue stain fungi). This suggests that at least some of the pines were harvested in salvage operations where their condition was likely a major factor in determining that they would be cut. We also encountered a few stands where many small- to medium-sized five needle pines had been cut. Perhaps this was done by managers who believed that the pines were bad future risks because of potential insect and disease problems.

Based on our surveys, we believe that the present level of mortality exhibited by sugar pines and western white pines in Southwest Oregon forests is high and a matter for concern. Especially ominous is our observation that substantial mortality is occurring in five-needle pines size classes from saplings to large trees. Not including cut stumps, 13 percent of the sugar pines and 17 percent of the western white pines in our survey stands were dead whereas only five percent of trees of other species in the same stands were dead. On a percentage basis, there was 2.5 times as much mortality of sugar pines as there was of other tree species in the same stands and 3.2 times as much mortality of western white pines as other species. Basal area of dead five-needle pines was substantial, reflecting the fact that the dying pines included many of the largest trees. For western white pines, fully 50 percent of the species' total basal area was accounted for in dead trees. For sugar pines, the figure was 30 percent. For other species in the same survey stands, 16 percent of the total basal area was accounted for by dead trees in the western white pine survey stands and 13 percent of the basal area was accounted for by dead trees in the sugar pine survey stands. There was 3.0 times as much basal area on a percentage basis in dead western white pines as in other species in the same stands and

2.3 times as much in dead sugar pines as in dead trees of other species in the same sample stands. Our surveys indicated that almost all of the mortality of sugar and western white pines in natural stands in Southwest Oregon can be attributed to the effects of diseases and insects, particularly white pine blister rust, which is especially damaging to smaller hosts, and mountain pine beetles, which are especially damaging to larger hosts.

Figure 47. White pine blister rust-caused topkill of western white pines, Southwest Oregon Cascade Mountains.

White pine blister rust is widely distributed on both sugar and western white pines in natural stands in Southwest Oregon. It is found virtually wherever the five-needle pine hosts occur, though amount of disease varies considerably with location and site condition. White pine blister rust was by far the major mortality agent of small sugar and western white pines (especially those under 20 cm (8 in) dbh) in the stands that we investigated. In addition, we found that many currently live sugar and western white pine saplings and small trees had *C. ribicola* infections on their boles or on branches within 15 cm (6 in) of their boles. Infections at these locations have a very high potential to have lethal consequences in the near term in trees of these sizes. Large five-needle pines in survey stands frequently exhibited top and branch death due to infection by *C. ribicola* but usually were not killed by the fungus acting alone (fig. 47). In most cases when dead, they showed evidence of infestation by mountain pine beetles as well.

White pine blister rust is very much influenced by climate and environmental conditions (Zambino 2010). Occurrence of favorable moisture and temperatures at key points during *C. ribicola*'s complex life cycle fosters disease, while disease development is limited or non-existent when marginal or unfavorable conditions dominate. The pathogen is favored on its alternate hosts by cool, moist conditions in spring and summer when infection and subsequent intensification and build-up of

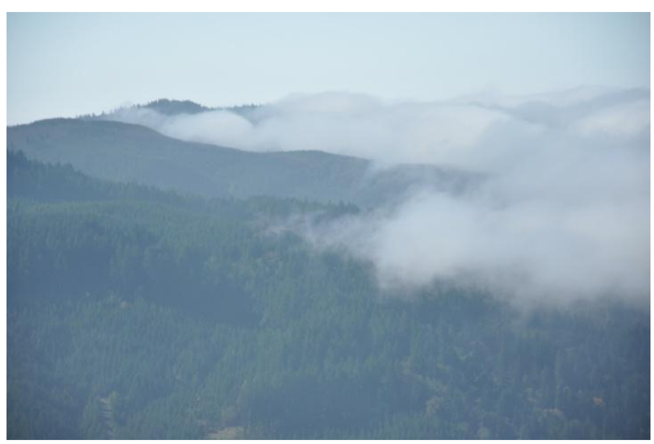


Figure 48. Moist conditions upslope and on ridgetops contributes to high hazard for pine infection by *C. ribicola* in late summer and early fall.

inoculum occur on leaves of these species. Even more critical, cool, wet conditions in late summer or early fall are essential for successful infection of pine hosts. Occurrence of 100 percent relative humidity and a temperature of 20º C (68 degrees F) or less for a period of at least 48 hours during this time of year are required for pine needle infection (Van Arsdel et al. 1956). Southwest Oregon has a Mediterranean climate. Dry, warm weather in late spring, summer, and early fall is common. Thus, conditions favorable for *C. ribicola* infection do not occur everywhere in every year. Infection is episodic in cooler, wetter years and more common and severe on sites and microsites where cool and moist conditions are more prevalent (fig. 48). Our results indicated that disease severity tended to be greatest in surveyed natural stands in Southwest Oregon in the Plant Series with lower average temperatures, on cooler, moister aspects, at higher elevations, on flat areas and gentle slopes, and in lower or upper third slope positions within local topography. Disease severity may be amplified for five-needle pine regeneration in openings or plantation settings that lack overstory trees to ameliorate conducive climatic conditions. We cannot provide specific information on this situation since our surveys did not include plantations or young stands in openings.

Almost all *Ribes* spp. that commonly occur in Southwest Oregon are highly susceptible to *C. ribicola* infection (Kimmey 1935) and can act as alternate hosts for the pathogen. However, some species are believed to be more important than others as regards their roles in contributing to infections of five-needle pines. *Ribes* spp. encountered in our surveys that fall into this category are *R. sanguineum* and *R. bracteosum* (Zambino 2010). While we did collect information on occurrence, abundance, and percent ground cover of all *Ribes* spp., we did not take plot level data by species and thus cannot comment on the relative importance of different species in our evaluation. As our survey was also done over the course of many months over two years, we could not consistently evaluate occurrence or severity of *C. ribicola* infection of *Ribes* spp.

Close proximity and abundant occurrence of *Ribes* spp. within a stand are not necessary for successful *C. ribicola* infection of Southwest Oregon five-needle pines. This is in spite of the fact that the delicate, short-lived basidiospores involved in spread from alternate hosts to five-needle pines are wind-dispersed and subject to rapid desiccation in dry air. Thus, incidence of pine infection in many situations declines sharply with distance from a *Ribes* spp. source (Van Arsdel 1960), and is often negligible when distances exceed a few hundred meters (Buchanan and Kimmey 1938, Kimmey and Wagner 1961). In our surveys, *C. ribicola* infection was common on five-needle pines in a considerable number of stands where no *Ribes* spp. were encountered as well as in stands where *Ribes* spp. were found in plots. Possible explanations for substantial amounts of infection in the stands without detected *Ribes* populations include: 1) there may in fact have been *Ribes* spp. within a few hundred meters of some of the stands but not actually in plots; 2) It has recently been shown that *Castilleja* spp. (paintbrushes) and *Pedicularis* spp. (louseworts) can function successfully as alternate hosts of *C. ribicola* in some situations (McDonald et al. 2006, Mulvey and Hansen 2011). The roles of these additional alternate host plants have not been evaluated in sugar and western white pine systems in Southwest Oregon, and we do not know if they can contribute to infection on these two pine species here. Both *Castilleja* and *Pedicularis* spp. occur and are sometimes plentiful in areas where sugar and western white pines occur in Southwest Oregon. Incidence of these possible alternate hosts was not determined in our surveys but plants were undoubtedly present in or near some survey stands; 3) We are convinced that *C. ribicola* basidiospores can in some cases be carried in fog that forms in low areas, canyons, and valleys where infected alternate hosts are plentiful and then be moved upslope in cloud banks for considerable distances. Not infrequently in Southwest Oregon, clouds that originate in valleys and canyons rapidly reach and then linger in higher elevation areas (fig. 48). The phenomenon of persistent, hanging clouds is particularly common in late summer and early fall in some years. High levels of five-needle pine infection by white pine blister rust show a close association with the kinds of sites where clouds and fog banks are most likely to persist, especially ridge saddles, high flats, and concave areas on ridges. Van Arsdel (1965) demonstrated that long distance transport of *C. ribicola* basidiospores and associated infection of five-needle pine hosts can occur in other parts of the country when rising air masses generate fog and valley inversions limit subsequent downslope air movement.

There is very little information specific to the biology and impacts of mountain pine beetles on sugar and western white pines. However, based on our evaluation, mountain pine beetles were by far the most important mortality agents of larger sugar and western white pines on most sites in Southwest Oregon (fig. 49). Infestation is common and widespread, with mountain pine beetles showing an impressive ability to locate and kill often widely scattered or isolated five-needle pines in mixed stands as well as hosts in clumps. In a testimonial to the high susceptibility of the five-needle pines to mountain pine beetles in the area, our surveys showed that with mountain pine beetle populations at endemic levels, sugar pines were much more frequently infested than ponderosa pines in cases where both occurred in the same stands and western white pines were more often

Figure 49. Extensive mortality of large sugar pines caused by mountain pine beetles, Southwest Oregon Cascade Mountains.

infested than lodgepole pines where they occurred together. Aerial survey results indicate that mountain pine beetle infestation in Southwest Oregon five-needle pines is less closely tied to particularly dry weather cycles than is infestation in other pine hosts with fairly consistent detection of beetle-caused mortality in five-needle pines most years, irrespective of annual weather conditions.

The major factor predisposing sugar and western white pines to mountain pine beetle infestation in Southwest Oregon forests appears to be high stand densities (fig. 50). In our survey stands, average basal area for all trees in plots with mountain pine beetle infested sugar or western white pines was a third again as great as that in plots with live, uninfested pines of these species. In Southwest Oregon, current high stand densities that probably contribute to weakening pines and possibly favor mountain pine beetles themselves by providing preferred environmental conditions under deeper shade can be attributed to fire exclusion over the past 60 to 80 years in areas that previously had high frequency, relatively low severity fire regimes. Natural fires regulated stand densities and in their absence large amounts of regeneration often involving shade tolerant tree species has proliferated and is now crowding the five-needle pines as well as other seral tree species. We believe that as suggested by Dolph in the 1970s (personal communication), sugar and western white pines are at elevated risk of mountain pine

Figure 50. High stand density around a large sugar pine contributes to decreased tree vigor and influences behavior of mountain pine beetles.

beetle infestation in Southwest Oregon when surrounding stand basal area exceeds 32 m^2 per hectare (140 ft^2 per acre). Basal areas observed in plots with sugar pines and western white pines of 12.7 cm (5.0 in) dbh or greater that were not infested by beetles in our surveys averaged 38.8 m^2 per hectare (169 ft^2 per acre) and 37.2 m^2 per hectare (162.6 ft^2 per acre) respectively; the basal area represented by the trees around each of the five needle pines in these plots averaged very close to32 m^2 per hectare (140 ft^2 per acre). If retaining medium-sized and large sugar or western white pines in natural stands in Southwest Oregon is a desired management objective, stocking control using mechanical treatments or through reintroduction of fire seems essential.

Besides high stand density, diseases appear to play a lesser but still important role in predisposing five-needle pines to mountain pine beetle infestation, and they may interact with high stand densities in weakening pine hosts. About 20 percent of the mountain pine beetle infested sugar and western white pines in our survey stands showed detectable evidence of prior infection by *C. ribicola*. Percent infection of beetle-infested trees was probably actually higher than that because we were quite conservative in rating dead trees as infected. We found that it was often very difficult to identify blister rust infections on branches and tops of large dead trees that had been dead for more than five years, particularly when the trees were still standing. In the small number of stands in our survey where sugar pines were infected by *A. ostoyae*, large dead trees with roots colonized by the fungus always exhibited mountain pine beetle galleries as well, suggesting that the root disease was an important predisposing agent to bark beetle infestation.

In addition to mountain pine beetles, pine engraver beetles play a role in infesting and killing western white pines in Southwest Oregon (fig. 51). They can be found in combination with mountain pine beetles but frequently infest western white pines by themselves on sites with ultramafic soils in the Siskiyou Mountains. In this latter situation, they are found killing small to medium-sized hosts in more densely stocked portions of stands. Serpentine, peridotite, and related soils that have weathered from ultramafic rock have very high concentrations of magnesium, iron, and silica reflecting the unique elemental composition of their parent rock. This chemical composition is unsuitable for survival of numerous plant species, and even for western white pine, a species that can survive on such soils, provides

Figure 51. *Ips* spp. galleries on western white pine.

suboptimal growing conditions. Thus, western white pines on ultramafic soils apparently have lesser vitality and greater vulnerability to what are considered to be less aggressive bark beetles than are western white pines that are growing on more fertile soil types. Western white pine dwarf mistletoe infects many western white pines on sites with ultramafic soils and may aid in predisposing hosts to engraver beetles as may white pine blister rust infections.

Sugar pines and western white pines are very resistant to most root disease pathogens that occur in Southwest Oregon (Hadfield et al. 1986). They often remain healthy in natural stands on sites where there are substantial amounts of infection and killing of associated tree species by *Phellinus weirii, Heterobasidion occidentale, Leptographium wagneri, Phytophthora lateralis,* and/or *Armillaria ostoyae*. In general if not affected by white pine blister rust, sugar and western white pines appear to be excellent species for retention on sites in Southwest Oregon where root disease mortality is impacting other conifer species. The possible exception is sugar pines in certain stands with Armillaria root disease. In our surveys, we found that sugar pines were vulnerable to Armillaria root disease on some infested sites, especially in the northern part of the area examined in this evaluation. Sugar pines were not impacted by the disease on other infested sites. There did not appear to be consistent, identifiable site differences associated with vulnerability or lack of vulnerability. A choice to favor sugar pines in an area with Armillaria infection centers in Southwest Oregon should be based on a careful local evaluation of existing disease effects. Armillaria root disease is known to be a very significant mortality agent of sugar pines to the east of our evaluation area (Kanaskie, personal communication). The common occurrence and wide distribution of root diseases on other conifer hosts indicated by the results of our surveys should be a matter for concern.

The Siskiyou-Klamath Region of southwestern Oregon and northwestern California is considered to be the area of greatest diversity of dwarf mistletoes in the United States with 11 taxa of *Arceuthobium* spp. occurring on and effecting 21 taxa of conifer hosts (Mathiasen and Marshall 1999). Dwarf mistletoe infection is common and widely distributed on many conifer species, and tree mortality and growth impacts due to these parasitic flowering plants can be very substantial in Southwest Oregon. This is especially true on such vulnerable and severely damaged hosts as Douglas-fir and mountain hemlock. Impacts on five-needle pines appear to be generally much less serious. In the area examined in this evaluation, dwarf mistletoe infection is virtually unknown on sugar pines and none was encountered in any of our survey stands. Western white pine infection by dwarf mistletoe does occur in Southwest Oregon but in rather specific situations. Based on our surveys, dwarf mistletoe infection may be a matter of some concern where western white pines are growing in combination with mountain hemlocks in the higher Cascades as well as on western white pines in stands on ultramafic soils in the Siskiyou mountains. In many other situations, western white pines will not be infected by any dwarf mistletoes and, as with sugar pine, if otherwise healthy should be appropriate species for retention in stands where associated conifer species are being damaged by *Arceuthobium* spp.

This evaluation was not designed to gain extensive information on wildlife use of sugar and western white pine in Southwest Oregon, but we did collect data on the occurrence of detectable wildlife excavations 2.5 cm (1.0 in) diameter or greater on all trees in survey stands. We found that both five-needle pine species and particularly sugar pine showed relatively large numbers of excavations, most of which appeared to be nesting cavities, and they were among the most important of all tree species for this kind of wildlife use based on frequency of observed excavation occurrence (fig. 52). Sugar pine has been reported to be a particularly important species in this respect by other investigators (Jimerson 1996). A caveat concerning the importance of wildlife use of sugar and western white pines of the type we observed is that most cavities detected in our surveys were in dead trees, especially large dead ones. To take advantage of this apparent preference in managing habitat would require maintaining a substantial population of large five-needle pine snags (which currently exists) but also populations of large live five-needle pines for future recruitment (perhaps not as dependable a future resource).

Figure 52. Avian excavation in sugar pine snag, Southwest Oregon Cascade Mountains.

In this evaluation, we present data based on a single time evaluation showing relatively recent insect- and disease-caused mortality levels for sugar and western white pines in Southwest Oregon. Unfortunately, we lack long-term mortality information for sugar and western white pines on an area-wide basis here. Have these pine species been suffering similar high levels of mortality for many years? There is certainly a large amount of anecdotal information that suggests so. Were these species more widely distributed and more plentiful in the past? Quite likely, but a straight-forward approach to answering that question eludes us. There is a notable lack of quantitative data on the long-term impacts of diseases and insects on sugar and western white pine in Southwest Oregon or on the historic demographics of the two pine species here. Intriguing tidbits concerning declines in the occurrence and numbers of these species in a few limited areas over time do exist:

> 1) Data from a timber inventory initiated in 1957 that originally involved 325 plots arranged on a systematic grid on the Umpqua National Forest (Petrick unpublished) was compared with data from a comparable (although not identical) plot grid (CVS) established in the mid-1990s. Results showed that, overall, there was a 20 percent decrease in number of plots with live five-needle pines. For trees greater than 12.7 cm (5.0 in) dbh, plots with living western white pines decreased by 50 percent while those with sugar pines declined by 8 percent.

Unfortunately, data were not collected on trees < 12.7 cm (5.0 in) dbh in the 1957 reading but they were included starting in 1968. For trees less than 12.7 cm (5.0 in) dbh, plots with living sugar pines decreased from 27 to 19 percent between 1968 and the mid-1990s while for western white pines, the number of plots decreased from 20 to 15 percent;

2) Panther Mountain, the area reported to have the earliest detected white pine blister rust on sugar pine in Southwest Oregon (Mielke 1938) was revisited in 2008 (Goheen and Mallams unpublished). At the time of the initial survey in 1937, 112 sugar pines were examined in a 12 hectare (30 acre) area on the east slope of the mountain just below the summit. In 2008, the same 12 hectare (30 acre) area was systematically surveyed and no living sugar pines and only one identifiable sugar pine snag were found. *Ribes* spp. with *C. ribicola* infections were encountered in the survey. The original investigators also reported scattered living but blister rust-infected sugar pines on the summit of the mountain and on the east and west slopes for a distance of 1.6 km (1.0 mile) in both directions. No sugar pines were seen in these locations in 2008.

3) The Mill Creek 0.4 hectare (1.0 acre) permanent plot initially surveyed in 1952 (fig. 53) on the Rogue River National Forest (Showalter, Fullmer, Watsom, and Miller unpublished) was relocated and resurveyed in 2009 (Goheen and Mallams unpublished). At the time of the original survey, the plot contained 422 live sugar pines well-distributed among size classes; when revisited, it was found to contain 130 live sugar pines 95 percent of which were seedlings and saplings. Most of these small trees appeared to be in poor condition due to overtopping by Douglas-firs and incense cedars. In 2009, 14 dead sugar pines between 12.7 and 50.0 cm (5.0 and 20.0 in) dbh with mountain pine beetle galleries were observed on the plot. An additional 10 dead trees in this size class, though still identifiable as sugar pines, were too deteriorated to accurately determine the causes of death. Two large sugar pine stumps were present. Evidence of other trees observed in the original survey was completely gone.

Figure 53. Survey tag from "Blister Rust Control (BRC) Disease Survey", 1952, Southwest Oregon Cascade Mountains.

4) A well-documented case of disease-caused extirpation occurred between the 1960s and 1990s in western white pine at the Champion Mine site on the Cottage Grove Ranger District, Umpqua National Forest (Kinloch et el. 1999, G. Barnes and R. Sniezko, personal communication). Here, conditions were very favorable for white pine infection by *C. ribicola* but, though many white pines were infected and died, there were a substantial number that exhibited an apparently very high level of resistance to the pathogen. In 1958 and 1959, 95 canker-free trees were selected at the site for the genetic resistance program, among the first selections in the Pacific Northwest program. Unfortunately, in 1968 the parent trees began to exhibit evidence of white pine blister rust cankers and die. All were dead by 1994 (fig. 54). It was found that the selected western white pines at the Champion Mine site indeed had a single major gene that conferred resistance to the original wild strain of *C. ribicola* via a hypersensitive needle reaction. However, a local race of the pathogen had evolved a virulence gene that overcame the single gene resistance.

Figure 54. One of the original selected trees at the Champion Mine site. Photo courtesy of G. Barnes, USFS retired, Dorena Genetics Resource Center.

The death of western white pines at the Champion Mine site was notable for its rapidity and completeness. No mature western white pines occur there now and natural regeneration is rare. The Champion Mine case demonstrates the ability of a virulent introduced pathogen to virtually eliminate its hosts locally and points out the importance of employing multiple gene resistance (also known as partial resistance) in a sustainable genetics program. The Pacific Northwest White Pine Blister Rust Resistance Program focuses on multiple types of resistance today.

5) Dubrasich (2010) studied structure and composition of forest stands in ten "Areas of Special Interest" known to have precontact human use in the Upper South Umpqua watershed. Current stands were sampled for tree ages, tree characteristics, and fire histories. Logistic regression analysis was used to create age/diameter models and stands were back-dated using increment core data and tree positions to create stand statistics for 185 years prior to measurement. Changes in the number of trees and basal area over the past 185 years were calculated by tree species for each stand. Results indicated that in 1825 the ten sites had open, park-like stands with widely spaced trees. Currently, number of trees has increased 4.5 times on average and basal area has increased 2 to 12 times. Stands that were formally open and dominated by oaks and pines are now dense and dominated by Douglas-fir, true firs, and incense-cedar. In 1825, sugar

pines, which now occur at very low numbers, made up as much as a third of the stocking in the sample stands except those at high elevation.

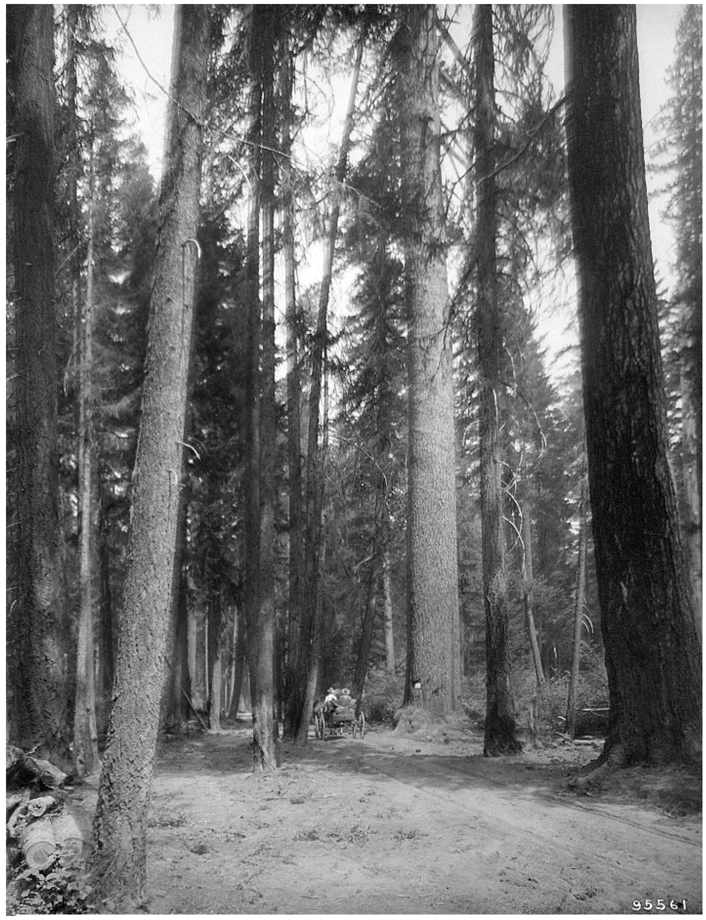


Figure 55. Sugar pines in the Prospect Corridor, Rogue River-Siskiyou National Forest, 1911. Photo from Forest Archives.

Sugar pines and western white pines are trees with great aesthetic, ecological, and economic value (fig. 55). In Southwest Oregon as elsewhere in the West, evidence is accumulating that they are being threatened by the combination of white pine blister rust, a disease caused by an introduced pathogen, infestation by mountain pine beetle, a density dependent bark beetle species, and substantial increases in forest stocking associated with fire exclusion (Conklin et al. 2009, Harvey et al. 2008, Samman et al. 2003, van Mantgem et al. 2004). All of these have been directly caused or greatly influenced by human activities. Five-needle pine restoration and management on federal lands is made even more challenging by the shift towards favoring late successional species and forest conditions over early to mid-seral species. If sugar and western white pines are to continue to be important components of natural stands and if restoration strategies for sugar and western white pines are to be successfully designed and implemented, we must manage them using appropriate, integrated, silvicultural prescriptions. Accurate monitoring that provides data on both the dynamics of five-needle pine populations and the causes of decline and mortality are essential. Appendix tables 7 and 8 provide location information on the natural stands surveyed in this evaluation. These can serve as benchmarks for measuring future health of sugar pines and western white pines in Southwest Oregon.

The Forest Health Protection staff at the Southwest Oregon Forest Insect and Disease Service Center is available to assist with assessing current conditions and developing site-specific five-needle pine management prescriptions and monitoring plans. However, the following general recommendations should apply:

MANAGEMENT RECOMMENDATIONS:
Five considerations for five-needle pines.

1. Include sugar and western white pines in management prescriptions.

Sugar pines and western white pines are excellent species for management in Southwest Oregon forests. They do well on a variety of soils and under a wide range of conditions, grow rapidly, attain large sizes, are resistant to most root diseases, are seldom damaged by dwarf mistletoes, produce valuable lumber, and contribute to superior wildlife habitat. They are trees of considerable aesthetic value and add substantially to forest diversity in mixed stands. Their wide ecological amplitudes and ability to tolerate a range of conditions suggest they may be good choices for reforestation and restoration in a changing climate. Though they do have serious problems, especially with white pine blister rust and mountain pine beetles, these can be greatly minimized through proper management. Openings created during harvest activities and in natural or prescribed fires are excellent opportunities to plant five-needle pines. This may be particularly true in the large stand-replacement fires we have experienced recently in Southwest Oregon where sugar pine and western white pine as well as other tree species have been killed over large acreages. Sugar pine and western white pine also may be especially appropriate for management on sites where other tree species are severely impacted by native root pathogens and/or dwarf mistletoes. Silviculturists are strongly encouraged to favor components of sugar and western white pines in as many management prescriptions as they can in Southwest Oregon.

In mixed-species stands on federal lands, slow losses in number and stature of single species are easy to ignore. We recommend that managers not be constrained by present occurrence or abundance of sugar or western white pines when considering their inclusion in management prescriptions. Though we lack data, we know that in our region, five-needle pines have been greatly impacted by white pine blister rust, mountain pine beetles, fire exclusion, and selective logging, especially in the past 80 years. Because of these impacts, we strongly believe that sugar and western white pines occur in smaller numbers in many Southwest Oregon stands than they once did. Furthermore, they may now be rare or not found at all in some stands where they occurred and may even have been plentiful historically. While these five-needle pines should always be managed in mixes with other appropriate site-adapted tree species, we encourage managers to show innovation in deploying sugar and western white pines in higher numbers and over wider areas in adaptive management prescriptions in the future. Provisions for monitoring results of such treatments should be included in management plans.

2. Plan ahead to ensure successful sugar and western white pine regeneration.

Evaluate white pine blister rust hazard during prescription development. High hazard sites are those where conditions are more favorable for the white pine blister rust fungus and/or where naturally occurring five-needle pines have previously exhibited severe levels of infection (35 percent or more of the trees infected).

When planting sugar or western white pines, use white pine blister rust-resistant, site-adapted planting stock from the proper seed zone (fig. 56). Since appropriate rust resistant stock developed through the Dorena Genetic Resource Center (www.fs.usda.gov/goto/r6/dorena) is available for Federal lands throughout Southwest Oregon, there is no reason why it should not be used preferentially in all planting operations. Personnel at the Dorena Genetics Resource Center and area geneticists can be relied on for advice on local performance and selection of appropriate planting stock.

Figure 56. Screening five-needle pine seedlings for resistance to *C. ribicola*. Photo courtesy USFS, Dorena Genetics Resource Center.

Instead of planting, managers may reasonably elect to depend on natural regeneration of sugar and western white pines on appropriate sites. Clearly, these should be limited to locations with low white pine blister rust hazard. On such sites in addition to currently-present regeneration, uninfected mature five-needle pine seed trees should be retained and protected.

3. Planting rust resistant stock may not be enough. Pruning to prevent or remove white pine blister rust infections may also need to be incorporated into five-needle pine management strategies. Furthermore, thinning prescriptions in stands with five-needle pines may need to be altered to increase the probability of success.

Pruning western white and sugar pines has been shown to be an effective treatment for preventing lethal infections by *C. ribicola* (Schwandt et al. 1994, O'Hara et al. 2010). The lowermost branches where infections are most likely to occur are removed to prevent infection, and those

Figure 57. Western white pine saplings pruned to remove and prevent further infection by the white pine blister rust fungus, *C. ribicola*.

branches with already existing cankers greater than 15 cm (6 in) from the main stem are removed to prevent them from developing into future bole infections. Early assessments of the white pine blister rust infection level in stands are critical for success. White pine blister rust infections may be well-established and lethal in many trees by the time stands are traditionally evaluated for stand management activities. Research suggests that thinning alone in young western white pine stand components may actually exacerbate white pine blister rust infection (Schwandt et al. 1994), while a combination of thinning and pruning that ultimately involves removal of branches in the bottom 2.5 to 3 m (8 to 10 ft) of the crown by the time that pine leave-trees are well spaced produces best results (fig. 57). Pruning can be done through several staged treatments that are started at a fairly early age and culminate at the time of thinning. During pre-commercial thinning, five-needle pines that exhibit blister rust infections on their boles or on branches within six inches of the bole should be preferentially removed as these trees are unlikely to survive in the long term.

4. Space medium- to large-sized sugar and western white pines to prevent mountain pine beetle infestation.

As sugar and western white pines get larger and older, they run considerable risk of becoming vulnerable to mountain pine beetle infestation. Management activities that promote and maintain pine vigor minimize this risk. Thinning stands with sugar or western white pine components or creating desirable spacing around individual five-needle pines within un-thinned stands are especially recommended treatments (fig. 58). We believe that basal area around sugar and western white pines in Southwest Oregon should be kept at or below 32 m² per hectare (140 square feet per acre) if at all possible. Proper spacing can be attained by mechanical treatments or prescribed fire. Preferred sugar and western white pine leave trees in thinning treatments should have live crown ratios of 25 percent or greater.

Figure 58. Density reduction treatment around an individual large sugar pine in a mixed conifer/hardwood stand, Siskiyou Mountains, Southwest Oregon.

5. Promote fire survival of five-needle pine stand components.

Sugar and western white pines are adapted to fire prone ecosystems but individual trees are not as resistant to fire damage as are such species as ponderosa pine. Removal of large accumulated duff mounds around the bases of mature trees, especially sugar pines, at least one year (preferably more) prior to prescribed burning is recommended to increase their survival potential.

The Southwest Oregon Forest Insect and Disease Service Center, Forest Health Protection, State and Private Forestry, Pacific Northwest Region serves the Rogue River-Siskiyou and Umpqua National Forests, the Roseburg, Coos Bay, and Medford Districts of the Bureau of Land Management, Oregon Caves National Monument, and other federal and tribal land management agencies in Southwest Oregon. We provide survey data, technical assistance, and training on matters related to forest insects and diseases.

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Appendix Table 1. Frequency of occurrence of Plant Associations determined for surveyed sugar and western white pine stands

Plant Association	Number of western white pine stands	Number of sugar pine stands
ABAM/ROGY/ACTR	1	
ABAM-TSME/VAME/ACTR	4	
ABCO/ACCI/OXOR		1
ABCO/BENE2	4	5
ABCO/BENE2/ACTR	1	1
ABCO/BENE2/LIBO	3	
ABCO/GASH-BENE2		2
ABCO/QUVA		2
ABCO/SYMO		1
ABCO-BENE2/LIBOL		1
ABCO-CADE27/TRLA6		3
ABCO-PIBR/CHUM-PYPI2		1
ABCO-PSME/ROGY		1
ABCO-TSHE/BENE2-LIBO	3	
ABMAS-ABCO/QUSA2/PYSE	1	
ABMAS-ABCO/SYMO/CHUM	2	
ABMAS-PICO/ARNE/CHUM	2	
CHLA/QUVA/XETE	3	
CHLA/QUVA/XETE & CHLA-LIDE3/GASH	1	
LIDE3/ARCTO3/XETE		1
LIDE3/CACH6/PILA		2
LIDE3/VAOV2-RHMA3-GASH		2
LIDE3-PIMO/QUVA/XETE	3	
LIDE3-PSME-QUCH2/RHDI6		3
PICO-ABCO-PSME	2	
PIJE-CADE27/QUVA	2	
PIMO3/XETE	2	
PIMO3-LIDE3/QUVA/XETE	1	
PIMO3-PIJE/QUVA/XETE	3	
PSME/ABCO		1
PSME/ACCI-BENE2		1
PSME/ARNE/SWO		1
PSME/GASH-BENE2		1
PSME/GASH-RHMA3		2
PSME/PIPO/RHDI6		3
PSME/QUCH2-LIDE3		1
PSME/QUVA		2
PSME/QUVA-ARNE/XETE		1
PSME-ABCO/SYMO		1
PSME-CADE27/BEPI2		1
PSME-PIPO/RHDI6		2
PSME-QUCH2/RHDI6		5
PSME-QUCH2-LIDE3		1
THPL/BENE2/POMU	1	
TSHE/ACCI-RHMA3	4	
TSHE/GASH/POMU SWO		2
TSHE/GASH-BENE2 SWO		1
TSHE/GASH-RHMA3-SWO	1	1
TSHE-ABCO/ACCI-BENE2		2
TSHE-PSME/GASH SWO	1	
TSME/RHMA3/XETE	1	
TSME/VASC/CHUM	3	
TSME-ABMAS/VAME/CHUM	5	

Appendix Table 2. Attributes of living and mountain pine beetle (MPB) infested sugar pines > 12.7 cm dbh (5 in)for 55 randomly selected sample stands: average basal area (BA) for plots with living vs. those with infested sugar pines (Pila) and average diameter at breast height (dbh) for living vs. infested sugar pines								
Survey Stand	**Ave. BA in m²/hectare for plots with Live Pila**	**Ave. BA in ft²/acre for plots with Live Pila**	**Ave. BA in m²/hectare for plots with MPB infested Pila**	**Ave. BA in ft²/acre for plots with MPB infested Pila**	**Ave. dbh (cm) of live Pila**	**Ave. dbh (in) of live Pila**	**Ave. dbh (cm) of MPB infested Pila**	**Ave. dbh (in) of MPB infested Pila**
SP1	59.7	260.1	60.8	264.8	53.8	21.2	45.7	18.0
SP2	55.1	240.0	NA	NA	76.2	30.0	NA	NA
SP3	17.4	75.8	60.8	264.8	89.1	35.1	106.7	42.0
SP4	27.5	119.8	67.5	294.0	76.7	30.2	71.1	28.0
SP5	34.8	151.6	NA	NA	39.1	15.4	NA	NA
SP6	56.5	246.1	NA	NA	99.3	39.1	NA	NA
SP7	27.5	119.8	71.6	311.9	51.8	20.4	118.9	46.8
SP8	44.3	193.0	72.5	315.8	112	44.1	104.1	41.0
SP9	18.4	80.2	45.9	199.9	142.2	56.0	116.8	46.0
SP10	53.7	233.9	NA	NA	122.7	48.3	NA	NA
SP11	41.3	179.9	110.2	480.0	128.3	50.6	76.2	30.0
SP12	29.8	129.8	76.4	332.8	116.3	45.8	120.1	47.3
SP13	18.4	80.2	36.7	159.9	65.3	25.7	83.3	32.8
SP14	20.9	91.0	32.1	139.8	111.8	44.0	83.8	33.0
SP15	26.9	117.2	29.8	129.8	47.7	18.8	50.8	20.0
SP16	33.3	145.1	30.5	132.9	87.6	34.5	145.5	57.3
SP17	20.7	90.2	55.1	240.0	73.4	28.9	71.1	28.0
SP18	42.2	183.8	43.6	189.9	84.6	33.3	101.6	40.0
SP19	78	339.8	64.9	282.7	102.9	40.5	92.2	36.3
SP20	27.5	119.8	46.8	203.9	81.3	32.0	86.4	34.0
SP21	33.3	145.1	NA	NA	39.4	15.5	NA	NA
SP22	27.5	119.8	45.9	199.9	57.7	22.7	90.2	35.5
SP23	16.1	70.1	59.7	260.1	54.1	21.3	63.5	25.0
SP24	36.7	159.9	NA	NA	86.4	34.0	NA	NA
SP25	55.1	240.0	71.8	312.8	81.3	32.0	93.2	36.7
SP26	54.3	236.5	34.4	149.8	78.5	30.9	147.3	58.0
SP27	36.7	159.9	48.6	211.7	46.7	18.4	34.8	13.7
SP28	33.7	146.8	21.3	92.8	50.8	20.0	96.5	38.0
SP29	52	226.5	48.9	213.0	77	30.3	99.1	39.0
SP30	40	174.2	60.4	263.1	89.9	35.4	54.4	21.4
SP31	44.4	193.4	70.9	308.8	98.8	38.9	66.8	26.3
SP32	14.9	64.9	21.3	92.8	66.3	26.1	96.5	38.0
SP33	34	148.1	33.7	146.8	39.4	15.5	35.6	14.0
SP34	18.4	80.2	24.8	108.0	100.1	39.4	101.6	40.0
SP35	46.8	203.9	NA	NA	61.2	24.1	NA	NA
SP36	41.8	182.1	NA	NA	66.8	26.3	NA	NA
SP37	58.5	254.8	51.9	226.1	68.3	26.9	86.4	34.0
SP38	65.2	284.0	74.6	325.0	102.6	40.4	78	30.7
SP39	44.4	193.4	64.3	280.1	87.6	34.5	99.1	39.0
SP40	55.1	240.0	71.6	311.9	101.1	39.8	112.8	44.4
SP41	44.3	193.0	NA	NA	81.3	32.0	NA	NA
SP42	57.4	250.0	71.8	312.8	144.8	57.1	135.4	53.3
SP43	18.4	80.2	31.2	135.9	56.1	22.1	49.3	19.4
SP44	44.7	194.7	59.7	260.1	105.9	41.7	160.8	63.4
SP45	52.8	230.0	67.7	294.9	94	37.0	60.4	23.8
SP46	20.7	90.2	97.3	423.8	93.7	36.9	93.2	36.7
SP47	20.1	87.6	18.4	80.2	75.2	29.6	61	24.0
SP48	34.4	149.8	53.5	233.0	74.4	29.3	72.9	28.7
SP49	50.5	220.0	54.6	237.8	50.8	20.0	72.1	28.4
SP50	59.7	260.1	71.6	311.9	79	31.1	103.6	40.8
SP51	25.2	109.8	57.4	250.0	118.4	46.6	86.4	34.0
SP52	50.5	220.0	45.9	199.9	74.4	29.3	48.3	19.0
SP53	51.6	224.8	88.8	386.8	67.8	26.7	40.6	16.0
SP54	36.7	159.9	41.3	179.9	70.6	27.8	53.3	21.0
SP55	34.4	149.8	64.3	280.1	90.7	35.7	45.7	18.0
All	**38.8**	**169.0**	**55.1**	**240.0**	**81.8**	**32.2**	**85.1**	**33.5**

Appendix Table 3. Attributes of living and mountain pine beetle (MPB) infested western white pines ≥ 12.7 cm dbh for 55 randomly selected sample stands: average basal area (BA) for plots with living vs. infested western white pines (Pimo) and average diameter at breast height for living vs. infested western white pines

Unit Number	Ave. BA (m^2/hectare) for plots with Live Pimo	Ave. BA (ft^2/acre) for plots with Live Pimo	Ave. BA (m^2/hectare) for plots with MPB infested Pimo	Ave. BA (ft^2/acre) for plots with MPB infested Pimo	Ave. dbh (cm) of live Pimo	Ave. dbh (in) of live Pimo	Ave. dbh (cm) of MPB infested Pimo	Ave. dbh (in) of MPB infested Pimo
WWP1	30.6	133.3	26.6	115.9	40.9	16.1	60.2	23.7
WWP2	37.9	165.1	18.4	80.2	114	44.9	97.3	38.3
WWP3	14.7	64.0	13.8	60.1	52.8	20.8	58.7	23.1
WWP4	4.6	20.0	29.8	129.8	60.2	23.7	51.3	20.2
WWP5	33.7	146.8	50.5	220.0	69.1	27.2	52.6	20.7
WWP6	45.9	199.9	55.1	240.0	82	32.3	103.9	40.9
WWP7	59.7	260.1	50.5	220.0	69.6	27.4	45.2	17.8
WWP8	36.7	159.9	45.9	199.9	28.7	11.3	98.3	38.7
WWP9	36.7	159.9	50.5	220.0	46.5	18.3	59.9	23.6
WWP10	NA	NA	61.3	267.0	24.6	9.7	49.3	19.4
WWP11	NA	NA	45.9	199.9	28.4	11.2	18.3	7.2
WWP12	14.7	64.0	82.6	359.8	26.4	10.4	21.3	8.4
WWP13	18.4	80.2	45.9	199.9	36.3	14.3	37.3	14.7
WWP14	NA	NA	NA	NA	NA	NA	NA	NA
WWP15	18.4	80.2	73.4	319.7	66.3	26.1	50	19.7
WWP16	78	339.8	91.8	399.9	68.6	27.0	17.8	7.0
WWP17	NA	NA	NA	NA	NA	NA	NA	NA
WWP18	30.6	133.3	73.4	319.7	94.5	37.2	72.4	28.5
WWP19	50.5	220.0	45.9	199.9	37.6	14.8	30	11.8
WWP20	NA	NA	45.9	199.9	NA	NA	69.6	27.4
WWP21	101	440.0	91.8	399.9	66.5	26.2	104.6	41.2
WWP22	91.6	399.0	73.4	319.7	51.3	20.2	39.4	15.5
WWP23	13.8	60.1	24.6	107.2	23.4	9.2	40.1	15.8
WWP24	54.2	236.1	78	339.8	62	24.4	70.1	27.6
WWP25	16.1	70.1	21.3	92.8	70.6	27.8	56.4	22.2
WWP26	61.2	266.6	48.2	210.0	90.9	35.8	76.2	30.0
WWP27	39	169.9	73.4	319.7	46.5	18.3	61	24.0
WWP28	24.5	106.7	41.3	179.9	69.1	27.2	57.7	22.7
WWP29	32.1	139.8	34.4	149.8	55.9	22.0	81.3	32.0
WWP30	NA	NA	52.8	230.0	45.7	18.0	45.7	18.0
WWP31	45.9	199.9	50.5	220.0	45.7	18.0	54.1	21.3
WWP32	NA	NA	110.2	480.0	NA	NA	53.3	21.0
WWP33	NA	NA	110.2	480.0	71.1	28.0	45.7	18.0
WWP34	78	339.8	73.4	319.7	78.7	31.0	78	30.7
WWP35	13.8	60.1	NA	NA	18.8	7.4	NA	NA
WWP36	15.3	66.6	NA	NA	22.3	8.8	NA	NA
WWP37	4.6	20.0	NA	NA	32.3	12.7	NA	NA
WWP38	18.4	80.2	58.1	253.1	71.1	28.0	49	19.3
WWP39	41.3	179.9	36.7	159.9	40.6	16.0	53.6	21.1
WWP40	32.1	139.8	NA	NA	35.6	14.04	NA	NA
WWP41	29.4	128.1	27.5	119.8	47.7	18.8	43.2	17.0
WWP42	54.2	236.1	64.3	280.1	31.2	12.3	38.1	15.0
WWP43	73.4	319.7	59.7	260.1	30.5	12.0	76.2	30.0
WWP44	36.7	159.9	91.8	399.9	88.1	34.7	78.7	31.0
WWP45	54.2	236.1	55.1	240.0	76.4	30.1	73.9	29.1
WWP46	12.2	53.1	NA	NA	30.5	12.0	NA	NA
WWP47	13.8	60.1	NA	NA	17.8	7.0	NA	NA
WWP48	NA	NA	41.3	179.9	53.3	21.0	71.1	28.0
WWP49	27.5	119.8	62	270.1	23.4	9.2	34.3	13.5
WWP50	NA	NA	NA	NA	NA	NA	NA	NA
WWP51	48.9	213.0	55.1	240.0	47	18.5	45.7	18.0
WWP52	NA	NA	73.4	319.7	96.5	38.0	69.1	27.2
WWP53	NA	NA	67.2	292.7	NA	NA	50	19.7
WWP54	39	169.9	36.7	159.9	69.8	27.5	66	26.0
WWP55	16.1	70.1	19.3	84.1	29.2	11.5	20.3	8.0
All	**37.2**	**162.0**	**54.4**	**237.0**	**52.8**	**20.8**	**55.9**	**22.0**

Appendix Table 4. Attributes of uninfested and pine engraver beetle infested western white pines ≥ 12.7 cm (5 in) dbh for 16 sample stands on ultramafic soils in the Siskiyou Mountains: average basal area (BA) for plots with uninfested vs. infested western white pines (Pimo) and average diameter at breast height for uninfested vs. infested western white pines				
Stand #	**Ave. BA in** m²/hectare (ft^2/acre) **for plots with Pimo but no infestation by engravers**	**Ave. BA** in m²/hectare(ft^2/acre) **for plots with Pimo infested by engravers**	**Ave. dbh** in cm (in) **of Pimo not infested by engravers**	**Ave. dbh** in cm (in) **of Pimo infested by engravers**
WWP3	10.1(44.0)	NA	55.4 (21.8)	NA
WWP4	14.2 (61.9)	52.8 (230)	89.4 (35.2)	35.6 (14.0)
WWP10	42.8 (186.4)	55.1 (240.0)	32.8 (12.9)	25.4 (10.0)
WWP11	36.7 (159.9)	NA	25.4 (10.0)	NA
WWP12	19.9 (86.7)	82.6 (359.8)	27.2 (10.7)	15.2 (6.0)
WWP23	16.1 (70.1)	22.9 (99.8)	28.2 (11.1)	24.1 (9.5)
WWP35	16.8 (73.2)	32.1 (139.8)	15.2 (6.0)	17.8 (7.0)
WWP36	15.3 (66.6)	9.2 (40.1)	22.1 (8.7)	22.9 (9.0)
WWP37	9.2 (40.1)	18.4 (80.2)	38.1 (15.0)	20.3 (8.0)
WWP40	33.7 (146.8)	NA	35.6 (14.0)	NA
WWP41	26.4 (115.0)	NA	46.7 (18.4)	NA
WWP46	18.4 (80.2)	NA	30.5 (12.0)	NA
WWP47	9.2 (40.1)	18.4 (80.2)	17.8 (7.0)	17.8 (7.0)
WWP48	36.7 (159.9)	NA	59.2 (23.3)	NA
WWP49	27.5 (119.8)	70.4 (306.7)	27.7 (10.9)	22.9 (9.0)
WWP55	17.0 (74.1)	26.0 (113.3)	31.0 (12.2)	17.0 (6.7)
All	**21.9 (95.4)**	**38.3 (166.8)**	**36.4 (14.3)**	**21.9 (8.6)**

Appendix Table 5. Relative pine bark beetle infestation rates for sugar and ponderosa pine plot trees $\geq$ 12.7 cm (5 in) dbh in sampled stands that contained both species						
Stand #	**Number of sugar pines in sample plots**	**Percent sugar pines infested by mountain pine beetle**	**Number of ponderosa pines in sample plots**	**Percent ponderosa pines infested by mountain pine beetle**	**Percent ponderosa pines infested by western pine beetle**	**Percent ponderosa pines infested by either pine bark beetle**
1	12	17	64	8	6	14
2	2	0	3	0	0	0
5	10	0	15	0	0	0
8	19	21	12	0	17	17
9	7	14	2	0	0	0
10	7	0	13	8	15	23
12	28	11	1	0	0	0
13	20	20	2	0	0	0
16	15	20	5	0	0	0
17	10	10	17	12	18	30
18	20	5	22	0	14	14
21	13	0	2	0	0	0
22	7	57	3	0	67	67
23	5	40	14	0	0	0
25	7	43	7	0	0	0
27	30	23	11	0	0	0
28	12	17	14	0	7	7
29	16	12	12	0	0	0
30	23	30	4	0	0	0
31	19	32	42	2	7	9
35	11	0	11	0	0	0
36	18	0	1	0	0	0
37	14	50	59	2	2	4
44	9	33	7	0	0	0
46	10	30	11	0	9	9
50	20	25	3	0	33	33
52	8	25	6	0	17	17
53	16	31	21	9	0	9
55	9	22	9	0	11	11
All	**397**	**20**	**393**	**3**	**6**	**9**

Appendix Table 6. Relative mountain pine beetle infestation rates for western white, lodgepole, and ponderosa pine plot trees ≥ 12.7 cm (5 in) dbh in sampled stands that contained more than one host species						
Stand #	**Number of western white pines in sample plots**	**Percent infested by mountain pine beetle**	**Number of lodgepole pines in sample plots**	**Percent infested by mountain pine beetle**	**Number of ponderosa pines in sample plots**	**Percent infested by mountain pine beetles**
1	12	58	28	21	0	0
2	10	40	2	0	0	0
5	8	37	2	50	0	0
8	4	25	0	0	6	0
9	17	23	14	50	3	0
12	13	8	8	0	0	0
13	24	17	15	13	0	0
15	11	18	8	37	0	0
16	5	20	3	0	0	0
19	4	25	6	17	0	0
22	5	20	3	0	0	0
25	17	47	13	8	2	0
27	8	12	0	0	1	0
38	7	43	1	100	0	0
39	11	82	2	50	0	0
42	13	46	4	0	0	0
46	5	0	2	0	0	0
47	4	0	30	7	0	0
48	3	33	2	0	0	0
49	12	25	26	0	0	0
All	**193**	**29**	**175**	**20**	**12**	**0**

Appendix Table 7. GPS locations of randomly selected stands with sugar pine components surveyed in this evaluation			
No.	**Name**	**Administrative Unit**	**GPS Coordinates**
SP1	Mill Creek Camp	High Cascades RD, RR-S NF*	N42.79274, W-122.47375
SP2	Needle Creek	High Cascades RD, RR-S NF	N43.83404, W-122.49937
SP3	Black Creek	Wild Rivers RD, RR-S NF	N41.95893, W-123.61489
SP4	Gray Butte	Wild Rivers RD, RR-S NF	N41.93528, W-123.60740
SP5	French Gulch	Siskiyou Mountains RD, RR-S NF	N42.04174, W-123.10697
SP6	Camp Creek	High Cascades RD, RR-S NF	N42.61669, W-122.38888
SP7	Dead Dog Gulch	High Cascades RD, RR-S NF	N42.64507, W-122.38597
SP8	Eva Creek	Diamond Lake RD, Umpqua NF	N43.23712, W-122.46603
SP9	Porcupine Spring	High Cascades RD, RR-S NF	N42.43193, W-122.39294
SP10	Mill Creek Divide	High Cascades RD, RR-S NF	N42.85121, W-122.43049
SP11	Coyote Creek	Tiller RD, Umpqua NF	N43.00787, W-122.72413
SP12	Experimental Forest	Tiller RD, Umpqua NF	N43.01784, W-122.72760
SP13	Scraggy Mountain	Siskiyou Mountains RD, RR-S NF	N41.98225, W-123.00935
SP14	Onion Creek	Wild Rivers RD, RR-S NF	N42.40455, W-123.64135
SP15	Onion Creek Road	Wild Rivers RD, RR-S NF	N42.39618, W-123.63185
SP16	Lookout Gap	Wild Rivers RD, RR-S NF	N42.34861, W-123.63562
SP17	Upper Elliot Creek	Siskiyou Mountains RD, RR-S NF	N41.98789, W-123.03899
SP18	Knutzen Cabin	Siskiyou Mountains RD, RR-S NF	N41.98835, W-123.05421
SP19	Dog Creek	Cottage Grove RD, Umpqua NF	N43.64889, W-122.69487
SP20	Brice Creek	Cottage Grove RD, Umpqua NF	N43.59580, W-122,58792
SP21	Grouse Loop	Siskiyou Mountains RD, RR-S NF	N42.05237, W-123.13013
SP22	Palmer Creek	Siskiyou Mountains RD, RR-S NF	N42.11661, W-123.12946
SP23	Upper Flumet	Siskiyou Mountains RD, RR-S NF	N42.13509, W-123.11081
SP24	Smith Creek	Roseburg District BLM	N42.84295, W-123.47726
SP25	Cow Creek Ridge	Medford District BLM	N42.81379, W-123.62503
SP26	Eden Valley	Powers RD, RR-S NF	N42.81010, W-123.85122
SP27	Slider Creek	Medford District BLM	N42.55440, W-122.93076
SP28	Pleasant Creek	Medford District BLM	N42.62050, W-123.15271
SP29	Elk Mountain	Medford District BLM	N42.52568, W-123.24325
SP30	Morris Creek	Medford District BLM	N42.51475, W-123.29066
SP31	Corridor	High Cascades RD, RR-S NF	N42.76306, W-122.48759
SP32	Upper Whiskey Creek	Wild Rivers RD, RR-S NF	N 41.99894, W-123.80994
SP33	Rough & Ready Creek	Medford District BLM	N42.08658, W-123.68841
SP34	Munger's Butte	Medford District BLM	N42.25410, W-123.36301
SP35	Waters Creek	Wild Rivers RD, RR-S NF	N42.40337, W-123.55487
SP36	Wonder Mountain	Medford District BLM	N42.35667, W-123.50996
SP37	Oregon Gulch	Medford District BLM	N42.05931, W-122.38720
SP38	West Fork Wolf Creek	Roseburg District BLM	N43.21361, W-122.94182
SP39	Steamboat Falls	North Umpqua RD, Umpqua NF	N43.37423, W-122.64861
SP40	Wilson Creek	North Umpqua RD, Umpqua NF	N43.29128, W-122.56462
SP41	Lemon Butte	North Umpqua RD, Umpqua NF	N43.47076, W-122.62611
SP42	Scaredman Creek	Roseburg District BLM	N43.38773, W-122.77436
SP43	Silica Mountain	Roseburg District BLM	N43.52795, W-122.78047
SP44	Soda Creek	Medford District BLM	N42.20168, W-122.40441
SP45	Schultz Creek	Roseburg District BLM	N43.00839, W-122.94481
SP46	East Fork Ashland Creek	Siskiyou Mountains RD, RR-S NF	N42.11064, W-122.71372
SP47	Seven Mile Peak	Gold Beach RD, RR-S NF	N42.50040, W-124.10040
SP48	Quosatana	Gold Beach RD, RR-S NF	N42.43150, W-124.25446
SP49	Smith/Winchuck Divide	Gold Beach RD, RR-S NF	N42.09047, W-124.01646
SP50	Dead Horse Ridge	Tiller RD, Umpqua NF	N42.75934, W-122.90845
SP51	Jackson Creek	Tiller RD, Umpqua NF	N42.95982, W-122.70010
SP52	Dads Creek	Medford District BLM	N42.78148, W-123.51880
SP53	Jenny Creek	Medford District BLM	N42.20634, W-122.32977
SP54	Budd Creek	Tiller RD, Umpqua NF	N43.03746, W-122.85036
SP55	West Fork Trail Creek	Medford District BLM	N42.67704, W-122.84830

*RR-S NF= Rogue River-Siskiyou National Forest

Appendix Table 8. GPS locations of randomly selected stands with western white pine components surveyed in this evaluation			
No.	**Name**	**Administrative Unit**	**GPS Coordinates**
WWP1	Sherwood Creek	High Cascades RD, RR-S NF*	N43.09070, W-122.28695
WWP2	Big Pine	High Cascades RD, RR-S NF	N42.39041, W-122.36903
WWP3	Wrangle Gap	Siskiyou Mountains RD, RR-S NF	N42.05065, W-122.84377
WWP4	Red Mountain	Siskiyou Mountains RD, RR-S NF	N42.05014, W-122.84209
WWP5	Hamaker	High Cascades RD, RR-S NF	N43.06816, W-122.33200
WWP6	North Fork Little Butte Creek	High Cascades RD, RR-S NF	N42.38575, W-122.35655
WWP7	Fish Lake	High Cascades RD, RR-S NF	N42.38917, W-122.34486
WWP8	Rogue River	High Cascades RD, RR-S NF	N42.99648, W-122.38163
WWP9	National Creek	High Cascades RD, RR-S NF	N42.97795, W-122.39782
WWP10	Rock Creek	Powers RD, RR-S NF	N42.68854, W-124.13267
WWP11	Iron Mountain	Powers RD, RR-S NF	N42.68631, W-124.12254
WWP12	North Fork of North Fork	Powers RD, RR-S NF	N42.70036, W-124.13887
WWP13	Three Lakes Snow Park	Diamond Lake RD, Umpqua NF	N43.10796, W-122.19064
WWP14	Whiskey Camp	High Cascades RD, RR-S NF	N42.90211, W-122.29110
WWP15	Upper Union Creek	High Cascades RD, RR-S NF	N42.85201, W-122.28253
WWP16	Diamond Lake	Diamond Lake RD, Umpqua NF	N43.18419, W-122.15792
WWP17	Cox Butte	High Cascades RD, RR-S NF	N42.32309, W-122.32008
WWP18	Daley Creek	High Cascades RD, RR-S NF	N42.31310, W-122.29014
WWP19	Barton Butte	High Cascades RD, RR-S NF	N42.27029, W-122.27597
WWP20	Cox Creek	High Cascades RD, RR-S NF	N42.31118, W-122.27109
WWP21	Loafer Creek	Diamond Lake RD, Umpqua NF	N43.30815, W-122.28982
WWP22	Lake Creek	Diamond Lake RD, Umpqua NF	N43.24988, W-122.16639
WWP23	Black Butte	Wild Rivers RD, RR-S NF	N41.93006, W-123.60655
WWP24	Divide Trail	High Cascades RD, RR-S NF	N43.09205, W-122.30791
WWP25	Bybee Creek	High Cascades RD, RR-S NF	N42.95422, W-122.40655
WWP26	Falls Creek	High Cascades RD, RR-S NF	N43.02401, W-122.30949
WWP27	Steve’s Fork	Siskiyou Mountains RD, RR-S NF	N42.00558, W-123.33020
WWP28	Old Highway	High Cascades RD, RR-S NF	N42.98208, W-122.39201
WWP29	Copeland Creek	High Cascades RD, RR-S NF	N42.98864, W-122.37678
WWP30	Cat Mountain Road	Cottage Grove RD, Umpqua NF	N43.61721, W-122.66433
WWP31	Grouse Mountain	Cottage Grove RD, Umpqua NF	N43.58278, W-122.62180
WWP32	Noonday Saddle	Cottage Grove RD, Umpqua NF	N43.59274, W-122.60924
WWP33	Upper Horse Creek	Cottage Grove RD, Umpqua NF	N43.59152, W-122.59597
WWP34	Swastika Mountain	Cottage Grove RD, Umpqua NF	N43.69796, W-122.65070
WWP35	Oregon Mountain	Wild Rivers RD, RR-S NF	N41.99543, W-123.78790
WWP36	Oregon Mountain Road	Wild Rivers RD, RR-S NF	N42.00671, W-123.77866
WWP37	West Fork	Wild Rivers RD, RR-S NF	N42.01596, W-123.77547
WWP38	Windago Pass	Diamond Lake RD, Umpqua NF	N43.36425, W-122.04514
WWP39	Bradley Creek	Diamond Lake RD, Umpqua NF	N43.35446, W-122.06968
WWP40	Cook and Green Pass	Siskiyou Mountains RD, RR-S NF	N41.93219, W-123.15344
WWP41	Pacific Crest Trail	Siskiyou Mountains RD, RR-S NF	N41.93268, W-123.15539
WWP42	Happy Camp	Diamond Lake RD, Umpqua NF	N43.10181, W-122.39146
WWP43	Fish Creek	Diamond Lake RD, Umpqua NF	N43.10646, W-122.38517
WWP44	Quartz Mountain	Tiller RD, Umpqua NF	N43.17911, W-122.68171
WWP45	Snowbird	Tiller RD, Umpqua NF	N43.18867, W-122.66740
WWP46	Hunter Creek Swamp	Coos Bay District BLM	N42.37326, W-124.30462
WWP47	Red Flat	Gold Beach RD, RR-S NF	N42.34380, W-124.29282
WWP48	Flycatcher Spring	Gold Beach RD, RR-S NF	N42.35456, W-124.29519
WWP49	Mud Lake	Powers RD, RR-S NF	N42.70622, W-124.12883
WWP50	Little Copland Creek	High Cascades RD, RR-S NF	N42.95898, W-122.28957
WWP51	Tuttle Creek	North Umpqua RD, Umpqua NF	N43.12459, W-122.97269
WWP52	Camp Grant	North Umpqua RD, Umpqua NF	N43.16502, W-122.86060
WWP53	Panther Ridge	North Umpqua RD, Umpqua NF	N43.27142, W-122.75462
WWP54	Deadman Pond	Roseburg District BLM	N43.08311, W-122.95616
WWP55	Chrome Ridge	Wild Rivers RD, RR-S NF	N42.46981, W-123.73083

*RR-S NF=Rogue River-Siskiyou National Forest